UNITED NATIONS

GENERAL ASSEMBLY

Distr.
GENERAL

A/AC.105/590
24 November 1994

ORIGINAL: ENGLISH

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

GLOBAL CHANGE: PARTICIPATION OF DEVELOPING COUNTRIES AND POSSIBILITIES OF ENHANCING IT

Note by the Secretariat

1. The Working Group of the Whole to Evaluate the Implementation of the Recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), at its eighth session (A/AC.105/571, annex II, para. 17) proposed that several studies on space applications should be undertaken by the Office for Outer Space Affairs in view of the recommendations adopted at the workshops, seminars, symposia and conferences organized by the United Nations Programme on Space Applications. The Working Group of the Whole identified a number of possible subjects for such studies, including the subject of the participation of developing countries in the global change programme and possibilities of enhancing it.

2. The report of the Working Group of the Whole was adopted by the Scientific and Technical Subcommittee in its report on the work of its thirty-first session (A/AC.105/571, para. 22), and the recommendations were endorsed by the Committee on the Peaceful Uses of Outer Space (COPUOS) in its report on the work of its thirty-seventh session[1] and by the General Assembly in its resolution 49/34 of 9 December 1994.

3. The present study has been prepared by the Secretariat in response to the request of the Working Group of the Whole. Its purpose is to stimulate the greater participation of specialists from developing countries in the Global Change Programme, which is an important part of the efforts to understand and preserve the global environment for humanity. The study was prepared using a variety of national and international sources, which are listed in the selected bibliography at the end of the study. It was also sent in draft form to external experts for comments. A summary of the study is provided below.

SUMMARY OF THE STUDY

4. The International Geosphere-Biosphere Programme (IGBP): A Study of Global Change was established in 1986 by the International Council of Scientific Unions (ICSU) to address the challenges of global change, recognizing that the complexity and importance of this topic required an international approach, with an emphasis on a soundly based framework for research planning, implementation and synthesis.

5. The objective of IGBP is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system and the manner in which they are influenced by human activities.

6. This overall aim encompasses a wide spectrum of research activities. To provide coherence, efforts are focused on the processes that affect global change on a decade-to-century time-scale, on those that are most susceptible to human perturbations and on those that will most likely lead to a practical, predictive capability. Emphasis on those features helped in the identification of initial priorities within the Programme and in the setting of realistic goals. The results of IGBP research are of very great importance to the Intergovernmental Panel on Climate Change (IPCC), thus providing scientific justification to the political process, for example, through the Framework Convention on Climate Change (FCCC) following the United Nations Conference on Environment and Development (UNCED), which was held from 3 to 14 June 1992 at Rio de Janeiro, Brazil.

7. The space technologies of interest to IGBP are primarily Earth observation technologies, including remote sensing of the environment and natural resources, and meteorological and climatic observations of the surface and atmosphere. Communications satellites, broadcasting satellites, navigation satellites and other space systems can also contribute in more indirect ways to the goals of IGBP. Compared with ground surveys, satellite observations provide less detail, but are more economical, particularly where repetitive monitoring is required. Large-scale phenomena or patterns that are not visible to a ground observer can often be seen on satellite images, and transboundary phenomena that can be logistically difficult to survey from the ground or air offer no difficulty for space observations. Environmental changes that occur gradually over periods of years or decades can be measured from the satellite data regularly acquired by the same sensors under the same conditions. Transient atmospheric or oceanographic phenomena can be followed by daily or hourly observations by meteorological or dedicated oceanographic satellites. Data obtained by space-borne instruments should be an integral part of the whole picture, composed of information gathered from all possible sources.

8. Three fifths of the land area and nearly all of the rich and varied tropical regions of the globe, which are also the repository of the bulk of global genetic diversity, are occupied by developing countries. They have the privilege and responsibility to study and understand this global environment scientifically. The applications and benefits from such an understanding are immediate and immeasurable.

9. The initial task of IGBP was to define critical gaps in the understanding of global biogeochemical cycles and life support processes, in order to focus future research efforts. Further review and planning carried out by the international scientific community resulted in the formulation of six key research questions which are described briefly in the present study. Each question is now addressed by an established Core Project, with an operational duration of approximately 10 years.

10. Throughout the development of IGBP, there has always been close collaboration with other relevant ICSU activities and with its two companion global change programmes, the World Climate Research Programme (WCRP) - organized jointly by ICSU, the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) - and the Human Dimensions Programme (HDP), organized by the International Social Sciences Council. These programmes are directed at physical and societal aspects of global change, respectively, and complement many areas of IGBP research. The three programmes together comprise the main international global change research effort now in operation. Many formal and informal links have been developed between these programmes and various bodies.

11. A three-category classification scheme of IGBP research has been developed and recommended by the Scientific Steering Committee (SSC) of IGBP to facilitate the process of definition and recognition of its component studies. The three categories and their main characteristics are: core research, which directly addresses the Science Plan goals of IGBP projects, is part of their formal structure and is coordinated by the relevant SSC; regional/national research, which is closely linked to Science Plan objectives (but may have

other overall aims), and is coordinated at a national or regional level; and relevant research, which makes an indirect contribution to the project, without formal affiliation.

12. Since the purpose of IGBP research is to provide new knowledge, it is unrealistic to try to forecast in detail the specific scientific products of the programme in five years. Nevertheless, it is possible, and desirable, to set goals and to define deliverable milestones against which progress can be assessed. While the precise outcome of the research is unpredictable, those responsible for funding the research need to know what general insights can be expected if support is provided at the level considered necessary for the implementation of the core projects' science plans.

13. All IGBP core projects will contribute individually to understanding important global change processes, and hence to model-based predictions of the behaviour of key features of the Earth system. Collectively, their potential is greatly enhanced as models can be constrained by the mass continuity in biogeochemical cycles and energy balances. However, additional problems are introduced as a result of the greatly increased complexity of the fully global approach as well as with simplifications needed in any attempt to dynamically link sub-component models. Therefore, it is not the aim of IGBP to produce a single, all-embracing global model that includes all known interactions between the very large number of biological, chemical and physical processes operating over the full spectrum of time and space scales. Instead, a suite of models, of varying complexity and realism, are being developed and employed to attack specific questions. This approach enables the predictive characteristics of the models to be tested against a variety of data sets, especially those generated for that purpose by the core projects.

14. IGBP research is not primarily directed towards the development of mitigation responses to counteract natural and man-made environmental change. Such work is more appropriate to engineers and agriculturalists, among others. Nevertheless, the results of IGBP will undoubtedly play a significant role in the assessment of mitigation strategies by providing the scientific underpinning that is needed, both for deciding whether a particular strategy is likely to be successful or not, and for evaluating its wider environmental consequences.

15. Comprehensive global observations are essential complements to the research programmes designed to improve our understanding of the Earth system. Such measurement systems will provide the means to monitor and detect the many facets of global change, and will provide the global data sets of long duration necessary for model calibration, validation and further development. Current operational observation systems (e.g. the World Weather Watch and Global Atmosphere Watch systems) do not fully meet this need because they were designed for more limited purposes.

16. Three closely linked global observational systems have been proposed to provide integrated, multiscale monitoring of global change: Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS) and Global Terrestrial Observing System (GTOS). The concept and scope of these systems are currently being formulated by ICSU in partnership with WMO, the United Nations Environment Programme (UNEP) and IOC of UNESCO, and the Food and Agriculture Organization of the United Nations (FAO). Since all three systems are primarily building on existing operational and research activities, their operational nature distinguishes them from the research programmes. However, IGBP must play a significant role in developing their scientific specifications and strategy-for-use and contributing to calibration, validation and other aspects of quality control.

17. Each of the global observation systems will need to develop procedures for efficient data management. IGBP is assisting in that exercise to ensure that the data sets help meet the needs of, and are accessible to, the research community. For satellite data, there are already close working links between the IGBP Data and Information System (IGBP-DIS) and the Committee for Earth Observation Satellites (CEOS) with which

IGBP has affiliate status. These links will be further developed, thereby assisting in the identification, prioritization and use of environmental data sets relevant to global change research. In addition, the regional collaboration through the IGBP System for Analysis, Research and Training (START) will provide a mechanism for both compilation of existing data and a structure for continuous monitoring of key variables.

18. The CEOS/IGBP-DIS Pilot Project was initiated at the sixth plenary meeting of CEOS in London in December 1992. Its objective is to assess the applicability of data exchange principles in support of global change research. One of the principles adopted at the plenary was that non-discriminatory access to satellite data by all users for global change, climate and environmental research and monitoring is essential. This should be achieved within the framework of the exchange and sharing mechanisms set up by CEOS members. CEOS invited IGBP-DIS to propose a pilot project for data use by IGBP Core Projects, in which the applicability of this principle would be tested for exchange of high resolution data. The project also involves commercial considerations, especially in relation to data from Landsat, SPOT, the European Remote Sensing (ERS) satellite and the Japanese Earth Resources Satellite (JERS).

19. Plans for a full suite of satellite-borne sensors in the late 1990s, specifically designed for environmental mapping and monitoring, are crucial to the success of IGBP. Yet there is also the potential for wider application of remote sensing systems that are already in operation, particularly the meteorological satellites operated by the United States National Oceanographic and Atmospheric Administration (NOAA). Although not originally intended for studies of global vegetation, the Advanced Very-High Resolution Radiometer (AVHRR) sensor carried on the NOAA satellites detects radiation separately in the red and infrared parts of the spectrum. The red spectral measurements are sensitive to the chlorophyll content of vegetation, and the near infrared to the mesophile structure of leaves. Taken together they provide information on a wide variety of important attributes of vegetation cover, including leaf area index, leaf biomass, net primary productivity and photosynthetic capacity. Methods are also being developed to use AVHRR data to determine land-surface temperature, the extent and frequency of biomass burning (forest and grassland fires) and evaporation-transpiration rates.

20. Practical and financial difficulties in gaining access to satellite data for environmental purposes have been a factor limiting the use of satellite data in many countries, particularly the developing countries. Member States of COPUOS have frequently expressed their concern over such high prices. Some actions have been taken to develop flexible pricing arrangements, including lower prices for research use, educational use and archival data.

21. Each year during the session of the Committee and its Scientific and Technical Subcommittee, Member States and particularly developing countries discuss the problems related to non-restricted and non-expensive access to space-related information. To facilitate this process, the existing nucleus of the International Space Information Service (ISIS) within the United Nations Office for Outer Space Affairs (OOSA) can be substantially expanded in cooperation with, and with the support of, other organizations. Possible next steps in this expansion process could include:

(a) Compilation of a list of activities and programmes conducted by different national and/or international organizations and agencies to provide a basis for better coordination;

(b) Development of a database where data from different Earth observation systems can be obtained in order to facilitate the availability of data for countries with little or no space research activity and, in particular, developing countries;

(c) Development of a database which will contain information for decision makers;

(d) Investigation of the role which the proposed regional centres for space science and technology education could play in disseminating and coordinating the compilation of Earth observation data;

(e) Development of databases with information on other space-related subjects, including space communication, meteorology, navigation and basic space science.

22. The further development of ISIS will provide all interested parties with direct access through the Internet to all information sources available. ISIS will also facilitate the organization of and search for space-related information on behalf of Member States and will provide advice on how such information can best be utilized.

23. In an effort to provide increased opportunities for advanced education to people from the developing countries, the United Nations, through OOSA, has begun an initiative to establish Centres for Space Science and Technology Education in each region covered by the regional commissions of the United Nations. The emphasis of the centres on educating educators will provide multiplier effect to ensure a long-term, adequate supply of trained specialists in the various disciplines required for sustainable development and environmental monitoring.

24. In the initial phase the centres will concentrate on providing an advanced education, research and applications development programme in remote sensing, satellite meteorology and geographic information systems. Improving data processing and information management capabilities in developing countries including archives of satellite data and links to international environmental databases, such as the UNEP Global Resource Information Database (GRID), will be an important element of the centres' functions. The centres will therefore make a major contribution to meeting the need (as identified in Agenda 21[2] of UNCED) to develop the capacities of developing countries to participate effectively in the global effort to protect the environment and ensure the sustainable development of all countries.

25. In the area of Earth observation systems, for example, the programme of each regional centre will:

(a) Develop skills and knowledge of university educators, environmental research scientists and project personnel in remote sensing and related technologies for subsequent application in national development and environmental management programmes;

(b) Assist educators in the development of environmental and atmospheric sciences curricula that they can use to advance the knowledge of their students in their own institutions/countries;

(c) Develop the skills of environmental research scientists and project personnel in the design, development and application of remote sensing techniques in natural resources management and biodiversity protection;

(d) Assist research scientists and project personnel in preparing space-derived information for presentation to policy and decision makers in charge of national and regional development programmes;

(e) Enhance regional and international cooperation in space science and technology programmes, particularly those that are related to environmental monitoring and natural resources management, and support and contribute to the work of institutions of higher education in each region and the activities of national/regional remote sensing user assistance and training centres;

(f) Assist in disseminating to the general public the value of space science and technology in improving their everyday quality of life.

26. The programmes will focus on teaching techniques and methods in environmental information systems as applied to educational, environmental and economic development issues. Case-studies using remote sensing and meteorological satellite data that can be processed, analysed and stored on micro-computer systems will be prepared in advance to provide hands-on illustrations of applications to specific natural resource surveys and to specific environmental monitoring and assessment exercises.

27. An integral part of each of these centres for space science and technology education will be a data management unit. Through this unit, each centre will have direct linkages with existing relevant global data centres and the nearest UNEP/GRID centres. Such linkages will enable those participating in the programmes of these centres to utilize the data in the archives of the data centres, particularly when they undertake projects that can benefit from their gaining such an access. Each centre will have direct access to the ESA Mercure satellite-based communications network proposed by European industry and European Space Agency (ESA) for the benefit of the United Nations and UNEP. The Mercure network would provide a modern, state-of-the-art global communication capability for the transfer of environmental data between different UNEP/GRID centres and between databases and archives and users of environmental data.

28. Each of these regional centres will be established in a major national science and technology-oriented university or research institution. Such an arrangement will enable the centres to optimally utilize the existing professional staff and physical infrastructure at the host institution. The participants in the programmes of the centres will also be able to collaborate with the graduates of existing training and user assistance centres on major research and application projects for the benefit of their countries. The establishment of the regional centres will require a strong commitment of support from the host countries as well as technical and financial assistance from developed countries and international organizations. Such assistance could take the form of full- or part-time technical specialists, data processing equipment and software, satellite data, funding for scholarships and other human, technical and financial resources.

29. The importance of the IGBP initiative and its achievements to date have been widely acknowledged and formally recognized at both the governmental and intergovernmental level. Its main work phase, with all established core projects operational, is just beginning. However, existing support is inadequate for full implementation. For that to be achieved, there must now be a long-term commitment to support both the research and its international infrastructure. The lack of funding for either component would seriously jeopardize the success of the programme.

30. Recognizing that developing countries are most vulnerable to the impact of global changes both in terms of economics and human welfare, and recognizing that IGBP provides a unique opportunity for developing countries to build an expert and self-reliant capacity in the interdisciplinary field of basic sciences for environment and development, all developing countries are encouraged to join IGBP and participate in it. There must be a national commitment to the programme and at least modest resources made available to their scientists. It is, however, the responsibility of scientists from developing countries to make decision makers in their own countries aware of the benefits that can be derived from the support of IGBP activities and that such support is in the overall national interest.

31. To facilitate the process of increasing the participation of developing countries in the IGBP programme, as well as in other programmes and projects involving space research and applications, COPUOS and its subsidiary bodies should make specific recommendations, based on their deliberations. COPUOS may wish, for example, to recommend the expansion of ISIS within the Secretariat to better serve the need for coordinating and expediting access to environmental databases and other sources of information. Similarly, the role of the proposed centres for space science and technology education in assisting IGBP activities of developing countries should be explored in more detail.

Notes

[1]Official Records of the General Assembly, Forty-ninth Session, Supplement No. 20 (A/49/20), para. 29.

[2]Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992 (United Nations publication, Sales No. E.93.I.8 and corrigenda), vol. I: Resolutions Adopted by the Conference, resolution 1, annex II.

Annex

GLOBAL CHANGE: PARTICIPATION OF DEVELOPING COUNTRIES AND POSSIBILITIES OF ENHANCING IT

Study by the Secretariat*

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*The present study has not been formally edited.

INTRODUCTION

1. For Earth system research – the study of global-scale interactions that determine the habitability of our planet – national and international collaboration between regional research groups should be extended all over the globe. It is apparent that no single unit or organization can accomplish this alone. There are three main reasons for this. First, such research encompasses many different disciplines, such as atmospheric chemistry and physics, oceanography, geology, terrestrial ecology, soil science, hydrology, and social science. The need for new working links among practitioners of these disciplines, and the pooling of intellectual resources, transcends the existing structures for scientific contacts, based on those traditional fields. Secondly, no single group can collect the many data sets that are needed for global scale analyses and agreement must be reached on sharing responsibilities for studies at different locations, and, as far as possible, common methodologies must be developed to ensure the compatibility of results. Thirdly, there is an urgency to such work, set by the political implications of increasing environmental degradation and concern for sustainable development. Ecologically and economically significant changes in soil, water and air quality have already occurred on a global scale. With an increasing human population, these are bound to be accentuated. Changes in climate occur, now not only as a result of natural variability but probably also because of human-induced changes in the composition of the atmosphere.

2. The International Geosphere-Biosphere Programme (IGBP): A Study of Global Change, was established in 1986 by the International Council of Scientific Unions (ICSU) to address these challenges of global change, recognizing that the complexity and importance of this topic required an international approach, with an emphasis on a soundly-based framework for research planning, implementation and synthesis.

3. The objective of IGBP is: "To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human activities."

4. This overall aim encompasses a very wide spectrum of research activities. To provide coherence, effort is focused on the processes that affect global change on the decade to century time-scale, on those that are most susceptible to human perturbations, and on those that will most likely lead to a practical, predictive capability. Emphasis on those features helped in the identification of initial priorities within the programme, and in the setting of realistic goals. The results of IGBP research are of very great importance to the Intergovernmental Panel on Climate Change (IPCC), thus providing scientific justification to the political process, for example, through the Framework Convention on Climate Change (FCCC) following the United Nations Conference on Environment and Development (UNCED) which was held from 3 to 14 June 1992 at Rio de Janeiro, Brazil.

5. The space technologies of interest to the IGBP are primarily Earth observation technologies, including remote sensing of the environment and natural resources and meteorological and climatic observations of the surface and atmosphere. Communications satellites, broadcasting satellites, navigation satellites, and other space systems can also contribute in more indirect ways to the goals of IGBP. Compared with ground surveys, satellite observations provide less detail, but are much more economical, particularly where repetitive monitoring is required. Large-scale phenomena or patterns that are not visible to a ground observer can often be seen on satellite images and trans-boundary phenomena that can be logistically difficult to survey from the ground or air offer no difficulty for space observations. Environmental changes that occur gradually over periods of years or decades can be measured from the satellite data regularly acquired by the same sensors under the same conditions. Transient atmospheric or oceanographic phenomena can be followed by daily or hourly observations by meteorological or dedicated oceanographic satellites. Of course, data obtained by space-borne instruments should be an integral part of the whole picture, composed of information gathered from all possible sources.

I. THE AIMS OF THE GLOBAL CHANGE PROGRAMME

A. Structure of the programme

6. The initial task of the IGBP was to define critical gaps in the understanding of global biogeochemical cycles and life support processes, in order to focus future research efforts. The initial priorities were outlined in IGBP Report No. 4 (1988). Further review and planning carried out by the international scientific community resulted in the formulation of six key research questions (IGBP Report No. 12, 1990); each is now addressed by an established Core Project, with an operational duration of approximately ten years. The Core Projects and the priority issues to be addressed by each project are described below:

a) How is the chemistry of the global atmosphere regulated, and what is the role of biological processes in producing and consuming trace gases? (International Global Atmospheric Chemistry project, IGAC). Priority issues: chemical transformations, biospheric sources and sinks (marine and terrestrial) of atmospheric constituents that have a role in controlling the global system, especially radioactive trace gases, aerosols and reactive radicals.

b) How will global changes affect terrestrial ecosystems? (Global Change and Terrestrial Ecosystems, GCTE). Priority issues: responses of natural and managed ecosystems to changes in climate, atmospheric composition and land use, with emphasis on both impact and feedback processes. These will be investigated experimentally and through the development of dynamic vegetation models and by examining the role of ecological complexity in the functioning of the global system.

c) How does vegetation interact with the physical processes of the hydrological cycle? (Biospheric Aspects of the Hydrological Cycle, BAHC). Priority issues: the effect of land surface properties (soil, vegetation and topography) on water, carbon and energy fluxes; temporal and spatial integration of those processes, including improved modelling of complex landscapes; and the down-scaling of climate information obtained from general circulation models.

d) How will changes in land use, sea-level rise and climate alter coastal ecosystems, and what are the wider consequences? (Land-Ocean Interactions in the Coastal Zone, LOICZ). Priority issues: the effects of changes in external forcing on coastal fluxes; coastal biogeomorphology and sea level rise; carbon fluxes and trace gas emissions; and the economic and social impact of global change on coastal systems.

e) How do ocean biogeochemical processes influence and respond to climate change? (Joint Global Ocean Flux Study, JGOFS). Priority issues: processes controlling the fluxes of carbon and associated biogenic elements within the ocean, and their exchanges with the atmosphere, sea floor and continental boundaries; interpretation and application of remotely-sensed ocean colour data.

f) What significant climatic and environmental changes occurred in the past, and what were their causes? (Past Global Changes, PAGES). Priority issues: high resolution reconstruction, at the global scale, of the changes occurring in the past 2,000 years; investigations of the more radical re-organizations of the global system during the most recent glacial/interglacial cycles.

7. Two other Core Projects are being developed for possible acceptance: Land Use/Cover Change (LUCC), and, in an early planning stage, the Global Ocean Euphotic Zone Study (GOEZS). (IGBP Report No. 28, 1994). In addition, three activities of an over-arching and integrative nature are now operational:

a) A Task Force on Global Analysis, Interpretation and Modelling (GAIM), responsible for promoting the development, evaluation and application of comprehensive prognostic models of the global biogeochemical system, and subsequently linking such models to those of the physical climate system.

b) The IGBP Data and Information System (IGBP-DIS), used to assist Core Projects in meeting their data acquisition and data management needs; as well as to facilitate collaboration with the space agencies, other data-producing bodies, and international data centres.

c) The Global Change System for Analysis, Research and Training (START), used to promote regional capacity building in global change science, and the establishment of networks for regionally-based research and analysis relevant to the origins and impact of global environmental change.

B. Relations with other programmes

8. Throughout the development of IGBP, there has always been close collaboration with other relevant ICSU activities and with its two companion global change programmes, the World Climate Research Programme (WCRP, organized jointly by ICSU, the World Meteorological Organization [WMO] and the Intergovernmental Oceanographic Commission [IOC] of the United Nations Educational, Scientific and Cultural Organization [UNESCO]) and the Human Dimensions Programme (HDP, organized by the International Social Sciences Council). These programmes are directed at the physical and societal aspects of global change, respectively, and complement IGBP research in many areas. The three programmes together comprise the main international global change research effort now in operation. Many formal and informal links have been developed between these programmes and other bodies. For example, START is jointly sponsored by all three programmes; LUCC is a joint initiative of IGBP and HDP. In addition to providing support for IGBP, JGOFS is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and IGAC is co-sponsored by the International Commission on Atmospheric Chemistry and Global Pollution (ICACGP), both of which are ICSU bodies. BAHC is strongly linked to WCRP's Global Energy and Water Cycle Experiment (GEWEX) project. The initial planning of the GOEZS effort is being co-sponsored by IGBP, SCOR and WCRP.

9. A joint WCRP-IGBP working group will coordinate the planning of large-scale field experiments that are of interest to GEWEX, BAHC, GCTE and IGAC. Four components have been accepted for further development within the WCRP: 1) the role of the stratosphere in the climate system; 2) the study of ozone depletion and related chemical processes in the upper atmosphere; 3) the monitoring of global change occurring in the stratosphere; and 4) the modelling and monitoring of UV-B penetration throughout the atmosphere. Such studies should provide the basis for a new WCRP project called "Stratospheric Processes and their role in Climate" (SPARC). GCTE and JGOFS will assist in developing links between SPARC and research groups considering of the biological effects of UV-B flux.

10. There are some fundamental differences in the working methods between social scientists and natural scientists. In dealing with environmental change, however, it is essential that these groups work together. Some work has already been undertaken, and some problems have been identified. Data are of considerable concern. Most social science data are collected according to political boundaries, that usually do not coincide with the ecological boundaries that are most suitable for the work of natural scientists. There are even important uncertainties with respect to what should be fully comparable factual data. For example, in a case study of deforestation in Brazil, it was pointed out that estimates of the current deforestation rate differed significantly. An analysis of Landsat images of the area performed at the University of New Hampshire (United States), revealed that the deforestation might be very dendritic (even fractal) in nature, and that the apparent amount depends upon the scale at which it is examined.

C. Components of the IGBP organizational structure

11. The Scientific Committee for the IGBP (SC-IGBP) consists of members appointed by ICSU, plus all Chairs of IGBP Scientific Steering Committees, Standing Committees and Task Forces. The Chairs of the WCRP Joint Scientific Committee and the HDP Committee also serve on the SC-IGBP as *ex officio* members,

together with a representative of the ICSU Advisory Committee on the Environment (ACE). The SC-IGBP was initially established in 1990 to follow-up on the work of the Special Committee for the IGBP. The responsibilities of the SC-IGBP are to develop a prioritized programme, guide its implementation and publicize its results. The SC-IGBP ensures overall integration within the programme, administers the central budget, develops collaborative links with WCRP and HDP, and serves as its liaison with ICSU and other organizations.

12. The IGBP Secretariat is responsible for carrying out the decisions of the Scientific Committee. It serves as the focus for planning and coordination, assisting the work on the Core Projects and ensuring the development of a common IGBP philosophy, which is necessary for the programme-wide integration of results. It is also responsible for publishing IGBP Reports, the Global Change Newsletter and other central publications. The Secretariat is located at the Royal Swedish Academy of Sciences in Stockholm.

13. The detailed planning and implementation of each Core Project is directed by a Scientific Steering Committee (SSC), appointed by the SC-IGBP. In addition, Standing Committees have been established for IGBP-DIS and START, and GAIM is led by a Task Force. Core Project Offices have been established to assist the SSG and SCs with their international communication and coordination responsibilities.

14. The IGBP Scientific Advisory Council (SAC) provides advice on the scientific content of the programme, assesses its results and makes recommendations on the general policies of the SC. It meets every 2-3 years and is composed of representatives of National IGBP Committees (NC) and liaison persons with other ICSU scientific members, under the Chairmanship of the ICSU President. Representatives of other organizations involved in global change research also attend.

15. The IGBP NCs also provide the formal interface between researchers in participating countries and the international structure. They are expected to assist with national planning and coordination; to contribute to the conceptual and practical development of IGBP as a whole; and to arrange the payment of national contributions towards the central costs of the programme. As of December 1993 there were 69 National Committees.

D. Categories of IGBP research

16. A three-category classification scheme of IGBP research has been developed and recommended by the Scientific Steering Committee of IGBP to facilitate the process of definition and recognition of its component studies. The three categories and their main characteristics are: Core Research which directly addresses the Science Plan goals of IGBP projects as part of their formal structure and coordinated by the relevant SSC; Regional/National Research which is closely linked to Science Plan objectives (but may have other overall aims), and is coordinated at a national or regional level; and Relevant Research which makes an indirect contribution to the project, without formal affiliation. Further details of this classification system are provided below:

a) Core Research Projects: These can be initiated directly by the SSC, adopted by the SSC, or be national or regional projects that have been accepted by the SSC on the basis that they provide components, which, when combined with projects from other national IGBP programmes, form a large-scale, internationally integrated research project. These projects are eligible for assistance in obtaining funds from national and international agencies. They will maintain close communication with the relevant Core Project Office.

b) Regional/National Research Projects: These projects arise from national IGBP committees or other national and regional groups of research organizations. Although not part of a Core Research Programme, they are an important part of the overall effort because they provide a critical link between

global scale Core Research and the national and regional scales which are of concern to individual countries and regions.

c) Relevant Research Projects: These are smaller projects initiated by individual investigators or institutions. They accumulate data through case studies and site-specific research and thus provide input to the broad knowledge that supports the overall effort. Some of these projects may be potential parts of a Core Research Programme, but are first considered by the appropriate national IGBP committee before being submitted to an SSC.

17. Even with these criteria, the classification of national projects may not always be clear-cut. Furthermore, the category allocation of a research activity may change according to its own development and the evolving priorities of the IGBP Core Projects. Since such changes are unavoidable, it should be noted that the categories are not based on scientific merit *per se*; but rather relate to research objectives, implementation procedures, and practical problems of dividing coordination responsibilities between the different levels of the Core Project structure. Core Research is expected to be of very high scientific quality though work of equally high scientific importance can also be found in the other categories.

18. For this conceptual structure to be functionally useful, the Core Project SSCs must be kept fully informed about all IGBP research being planned and carried out in their specific subject areas, and decide on what should be considered Core Research. In addition, the NCs must be aware of research at the regional/national level (with the involvement of regional START Committees, where appropriate).

E. Evaluating the progress of IGBP

19. The objectives and priorities of IGBP imply programmatic responsibilities relating to the assessment of global environmental change. Each Core Project is responsible for an ongoing assessment of scientific understanding in its field. In addition, GAIM is responsible for providing collective oversight within the programme and carrying out integrative studies. The output from these various assessment activities will be published.

20. With plans underway for a classification and summary of Core Project research for the IGFA Resource Assessment, information on the institutional resources will become available for each Core Project. In an effort to provide additional information to IGBP reviewers, IGAC has initiated plans for a bibliography or database of papers which have been produced as a result of IGAC research. It is realized that prompt publication of the scientific results of the IGBP in refereed international journals is essential, with due acknowledgement given that the work was performed as part of the IGBP. DIS is making plans for an IGBP Internet interface to provide general information about IGBP, and START is evaluating ways to connect areas which are not currently linked to Internet.

21. In addition to the internal mechanisms for progress assessment, the SC-IGBP has developed plans for an external evaluation of the programme to be conducted in 1994 and 1995, in cooperation with ICSU and IGFA. The evaluation will provide an independent assessment of the scientific results and the overall effectiveness of the programme. The review will be essential for an internal re-assessment by the SC-IGBP of its priorities and modes of action. It should also provide a solid basis for ensuring continued and adequate financial support for both the research projects and coordination functions.

22. Many IGBP scientists are also closely involved in the Science and Impacts Assessments of the IPCC. The IPCC is the body responsible for the scientific and technical assessment underlying the Framework Convention for Climate Change agreed upon at UNCED in June 1992. The IPCC was originally created in 1988 by the United Nations Environment Programme (UNEP) and the WMO. It is financed partly by these organizations and partly by voluntary contributions from various countries. IPCC is a reviewing, and not a

research body, and is therefore highly dependent on in-depth inputs from international programmes – particularly WCRP and IGBP. For the 1994 IPCC Report on Radiative Forcing of Climate (Working Group 1), IGBP researchers are contributing to reviews of the scientific research results on the carbon cycle, other trace gases and atmospheric chemistry, aerosols, radiative forcing, and the relative importance of emissions of different greenhouse gases.

23. The 1995 IPCC Scientific Assessment will be based on this material, with additional coverage of climate processes; observed climate variability and change; model predictions and validations; sea level rise; biotic responses to climate change and feedbacks to climate; and reducing uncertainties. IGBP scientists will contribute to most of these chapters and IGBP and WCRP, through their chairmen, will be jointly responsible for the final chapter in the Working Group 1 assessment, addressing the need for further research to reduce the uncertainties. While the 1990 IPCC Scientific Assessment strongly emphasized the physical components of the climate system, the 1995 Assessment provides for greater attention to be given to biospheric control of the atmospheric composition, feedback interactions with marine and terrestrial ecosystems, and the insights provided by palaeoclimate studies.

F. Expected outputs of the programme

24. Because the purpose of IGBP research is to provide new knowledge, it is unrealistic to try to forecast in detail the specific scientific products of the programme in five years. Nevertheless, it is possible – and desirable – to set goals, and define deliverable milestones, against which progress can be assessed. While the precise outcome of the research is unpredictable, those responsible for funding the research need to know what general insights can be expected if support is provided at the level considered necessary for the implementation of the Core Project science plans.

25. All IGBP Core Projects will contribute individually to our understanding of important global change processes, and hence to model-based predictions of the behaviour of key features of the Earth system. Collectively, their potential is greatly enhanced as models can be constrained by the mass continuity in biogeochemical cycles and energy balance. However, additional problems are introduced as a result of the greatly increased complexity of the fully-global approach, as well as simplifications needed in any attempt to dynamically link sub-component models. Therefore, it is not the aim of IGBP to produce a single, all-embracing global model that includes all known interactions between the very large number of biological, chemical and physical processes operating over the full spectrum of time and space scales. Instead, a suite of models, with varying complexity and realism, is being developed and employed, to attack specific questions. This approach enables the predictive characteristics of the models to be tested, against a variety of data sets, especially those generated for that purpose by the Core Projects.

26. IGBP research is not primarily directed towards the development of mitigation responses to counteract natural and man-made environmental change. Such work is more appropriate to engineers and agriculturalists, among others. Nevertheless, the results of IGBP will undoubtedly play a significant role in the assessment of mitigation strategies by providing the scientific underpinning that is needed, both for deciding whether a particular strategy is likely to be successful or not, and for evaluating its wider environmental consequences.

27. Thus IGBP studies (potential or already ongoing) may assist in evaluating various proposals for mitigation and/or amelioration strategies such as the disposal of fossil fuel CO_2 in the oceans; the enhancement of oceanic uptake of CO_2 via iron fertilization; the addition of chemicals to the upper atmosphere to reduce ozone depletion; the control of coastal erosion and the movement of littoral sediments arising from sea level rise and coastal subsidence; the diversion of rivers and creation of large freshwater reservoirs for climate control and water supply purposes; the sequestration of additional CO_2 by reforestation and afforestation; and the decrease of methane emissions from rice paddies by changing cultivation practices.

28. However, in most, if not all of these examples, the current understanding of the basic science involved can only provide a very crude estimate of the likely effectiveness and environmental consequences of the proposed action. In some cases it is arguable whether any of the anticipated benefits will be realized, while at the same time, many unknown risks of undesirable "side effects" remain. As scientific understanding improves in the next five years, it is hoped that IGBP will increasingly be able to provide the knowledge base on which the environmental (and economic) costs and benefits of such proposals can be assessed.

29. For at least the next 10-20 years, land-use change is likely to continue to be much more important than climate change in altering the global environment. The IGBP's proposed LUCC project, expected to be operational by 1995, will focus attention on those human activities that directly affect attributes of land cover, and their underlying driving forces (population, level of affluence, technology, political economy, political structure, and attitudes and values). Models will be developed to investigate the role of these factors in a variety of different environmental, historical and social contexts and their implications for biogeochemistry, ecological complexity and other aspects of global change. Close cooperation will take place among GCTE (with regard to its functional classification of vegetation types, and interests in global change impacts on agriculture and forestry); LOICZ (with regard to the effect of different land-use patterns on catchment basin dynamics and delivery, and changes of land use/cover in the coastal zone); and with PAGES (with regard to the possible role of pre-industrial land use changes on regional and global climate).

II. THE ROLE OF SPACE TECHNOLOGIES IN IGBP

A. The role of space technologies in global observing systems

30. Comprehensive global observations are essential complements to the research programmes designed to improve our understanding of the Earth system. Such measurement systems will provide the means to monitor and detect the many facets of global change, and provide the global data sets of long duration necessary for model calibration, validation and further development. Current operational observation systems (e.g., the World Weather Watch and Global Atmosphere Watch) do not fully meet this need, since they were designed for more limited purposes.

31. Three closely-linked global observational systems have been proposed to provide integrated, multi-scale monitoring of global change: the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). The concept and scope of these systems are currently being formulated by ICSU in partnership with WMO, UNEP, and UNESCO's IOC and the Food and Agriculture Organization (FAO). Because all three systems are building primarily on existing operational and research activities, their operational nature distinguishes them from the research programmes. However, IGBP must play a significant role in developing their scientific specifications and strategy-for-use, and contributing to calibration, validation and other aspects of quality control. Examples of relevant actions include:

a) GCTE assistance to GTOS in defining core measurements and field sites, with the latter covering both natural and managed habitats over a wide range of climatic regimes;

b) involvement in algorithm development for remote-sensing satellite data treatment;

c) the assembly of experimental global data sets (such as the IGBP-DIS 1 km Advanced Very High Resolution Radiometer (AVHRR) data set, to become part of the shared land surface component of GCOS and GTOS); and

d) the provision of advice regarding appropriate chemical, biological and optical measurements within the oceanic component of GCOS and the climate module of GOOS, based on techniques developed through JGOFS, particularly its time series studies.

32. Each of the global observation systems will need to develop procedures for efficient data management. IGBP is assisting in that exercise, to ensure that the data sets help to meet the needs of, and are accessible to, the research community. For satellite data, there are already close working links between IGBP-DIS and the Committee for Earth Observation Satellites (CEOS) with which IGBP has Affiliate status. These links will be further developed, thereby assisting in the identification, prioritization and use of environmental data sets relevant to global change research. In addition, the regional collaboration through START will provide a mechanism for both compilation of existing data and a structure for continuous monitoring of key variables.

B. CEOS/IGBP-DIS Pilot Project

33. The CEOS/IGBP-DIS Pilot Project was initiated at the Sixth Plenary of CEOS in London in December 1992. Its objective is to assess the applicability of data exchange principles in support of global change research. One of the principles adopted at the plenary was that "non-discriminatory access to satellite data by all users for global change, climate and environmental research and monitoring is essential. This should be achieved within the framework of the exchange and sharing mechanisms set up by CEOS members". CEOS invited IGBP-DIS to propose a pilot project for data use by IGBP Core Projects, in which the applicability of this principle would be tested for exchange of high resolution data. The project also involves commercial considerations, especially in relation to data from Landsat, the French System Probatoire dÓbservation de la Terre (SPOT) satellite, the European Remote Sensing satellite (ERS-1) and the Japanese Earth Resources Satellite (JERS). The project has now been extended to include data from the Indian Remote Sensing satellite (IRS-1) and its specific objectives are:

a) to ascertain what data are available from existing high spatial resolution satellite systems for global change research projects within IGBP;

b) to assemble databases from existing archives for selected IGBP Core Projects;

c) to develop and implement a data acquisition model for acquiring new high resolution data sets to support selected IGBP Core Projects; and

d) to provide the global change research community with ready access to these data at the marginal cost of reproduction.

34. The use of high-resolution data will be critical in answering the following questions for carbon cycle research: 1) What is the rate of deforestation in the tropics? 2) How much formerly forested land is in secondary succession? and 3) How much deforested land is abandoned each year?

35. A type of study carried out by IGBP requiring high-resolution data is one conducted along a transect of 1000 kms or more of a varying climate and/or ecosystem. For example, the North Australian Tropical Transect (NATT) is a research programme, extending from Darwin to Alice Springs, whose objectives are to determine the effects of soil and climatic variability, land management and global climate change on the savannahs of northern Australia. NATT takes advantage of the gradient of decreasing mean annual rainfall with increasing distance from the northern coast of the Northern Territory. A similar transect study is being conducted in West Africa. By comparing the results obtained from the two studies, the effects of vastly different human pressures will be seen.

36. Studies to be undertaken within the NATT programme include determination of land degradation within Australian tropical savannahs, emissions of trace gases during fires, effects of land management on the water cycle, and the development of cooperative programmes with local land care groups and, where appropriate, with state and federal agencies. The highest priority data requirement for this project will be to obtain recent data sequences (over the last two years) across the transect using Landsat or SPOT Imagery. It will also be important to have a long-term data archive (covering approximately 20 years) over several sites to assist in time sequence analysis of ecosystem change. A combination of Landsat and SPOT measurements will allow analysis of the functional characteristics of vegetation cover.

37. The BAHC programme of IGBP studies vegetation-water interaction on regional scales. This involves modelling of the water and energy balance, scaling algorithms, measurements of vegetation-water interaction, and surface fluxes. To this end, simultaneous satellite measurements are being conducted over several sites in Europe, North Africa, the United States, Russia and China. The areas investigated are the size of a SPOT scene (60x60 km), and their study usually covers five months of a year starting with the "green-up" phase and going to the "dry-down" conditions of vegetation. Frequent coverage of the area by high-resolution images are the highest priority requirements for this project. The overall requirements for the CEOS/IGBP-DIS pilot project concerned two transects (Australia and West Africa), the tropical forests in Africa and South America, and several smaller sites in European coastal areas (the Mediterranean and the Baltic), and an inland site in China. The total estimate of data required is of the order of 100 scenes per year of SPOT multispectral, 50 per year of SPOT-panchromatic, 300 per year of MOS and about 200 per year from the Landsat-thematic mapper.

38. The replies from the space agencies were positive and encouraging. The proposed availability of selected global change researchers up to 400 thematic mapper scenes per year at the "copying" price of $240 per scene. The National Space Agency of Japan (NASDA) reported the availability of approximately 300 scenes per year of MOS-Multispectral Electronic Self-Scanning Radiometer data over East and Southeast Asia, which could be purchased at the cost of $90 per scene. The French space agency, CNES, proposed a twofold arrangement to provide SPOT data to IGBP. Some SPOT scenes could be made available at a special price ($1200 per multispectral scene; $1500 per panchromatic scene) and a "limited number" of scenes would be made available at a reduced price of $200 per scene. The Indian Space Research Organization (ISRO) has offered IGBP researchers access, at a modest cost, to more than 10,000 scenes from the Landsat-thematic mapper, and IRS 1-A and 1-B data archived in digital form at the ISRO Centre in Hyderabad.

C. Biosphere-Atmosphere Field Experiment in Amazonia

39. In June 1992, at its third meeting in Greenbelt, Maryland (United States), the joint WCRP/IGBP Working Group on Land-Surface Experiments, suggested that a large-scale land surface experiment be conducted in Amazonia between 1997 and 1999. Meanwhile, the scientific plan has been further developed by the Brazilian National Space Research Institute (INPE). The main goals of the biosphere-atmosphere field experiment in Amazonia are to answer the following questions:

a) How does Amazonia currently function as a regional entity? This question addresses interactions with the Earth system in the form of exchanges of energy, water, carbon and other trace gases via atmospheric and river systems; and

b) How will human-induced change alter the function of the Amazon region? This question addresses modifications within Amazonia associated with replacing tropical forest with mixed replacement vegetation, and on indirect modification of the vegetation gradient in areas surrounding Amazonia.

40. To answer these questions, an experiment consisting of three linked field activities has been proposed: the Large-scale Atmospheric Moisture Balance of Amazonia using Data Assimilation (LAMBADA)

programme that constitutes the long-term monitoring and large-scale regional component of the experiment, the Biosphere-Atmosphere Transfers and Ecological In-Situ Studies (BATERISTA) programme and the Amazon Ecology and Atmospheric Chemistry Experiment (AMBIANCE), which represents the process-oriented field studies component of the experiment.

41. The LAMBADA programme would set in place a radiosonde network around and within the Amazon basin; precipitation, hydrography and surface meteorological networks within the basin; long-term monitoring stations of $C0_2$ and trace gases in at least six research sites within the basin; and a comprehensive satellite remote sensing programme. The field observation phase of LAMBADA would continue for approximately two years, probably in 1997 or 1998. In conjunction with meteorological fields provided by a mesoscale model 4-dimensional data assimilation (4DDA) scheme, LAMBADA would provide the data that would permit quantification of the energy, moisture and carbon budgets of the region and their dependence on the large-scale atmospheric circulation.

42. The BATERISTA programme is proposed as a coordinated set of process studies aimed at a better understanding of the micro-meteorological, eco-physiological and bio-geochemical controls on the exchange of energy, moisture, trace gases and momentum between the atmosphere and the vegetated land surface. The BATERISTA studies would also provide opportunities for the validation of remote sensing techniques and provide a framework for associated ecological studies. As proposed, six research areas located in different eco-climatic regions of the Amazon basin and surrounding regions are to be equipped with arrays of surface sampling equipment, flux towers and other hardware. Three of the research areas are to be the axis of an ecological gradient transect study.

43. The AMBIANCE programme is proposed as a study of the influence of the intact forest and of the consequences of forest conversion, agricultural practices and abandonment, and secondary succession, on regional and global biochemistry and atmospheric chemistry, focusing on ecosystems carbon dynamics, atmospheric greenhouse gases (CH_4, N_2O, CO_2) and the oxidizing potential of the atmosphere (O_3, CO, NMH, NO_x). Flux tower and aircraft gas concentration measurements, and satellite observations of land-use patterns will provide the basis for integrated measurements of fluxes at scales ranging from metres to kilometres in the Amazon basin. These data will be complemented with ecological monitoring studies along transects of climate and land-cover and land-use changes.

D. Use of meteorological satellite data for vegetation studies

44. Plans for a full suite of satellite-borne sensors in the late 1990s, specifically designed for environmental mapping and monitoring, are crucial to the success of IGBP. Yet there is also the potential for wider application of remote sensing systems that are already in operation, particularly the meteorological satellites operated by the United States National Oceanographic and Atmospheric Administration (NOAA). Although not originally intended for studies of global vegetation, the AVHRR sensor carried on the NOAA satellites detects radiation separately in the red and infrared parts of the spectrum. The red spectral measurements are sensitive to the chlorophyll content of vegetation, and the near infrared to the mesophile structure of leaves. Taken together, they provide information on a wide variety of important attributes of vegetation cover, including leaf area index, leaf biomass, net primary productivity and photosynthetic capacity. Methods are also being developed to use AVHRR data to determine land surface temperature, the extent and frequency of biomass burning (forest and grassland fires), and evaporation-transpiration rates.

45. A specific advantage of the AVHRR observation system is that it provides full global coverage every few days, greatly increasing the likelihood of obtaining a seasonal sequence of cloud-free images. In addition, there is a well established system of ground receiving stations for data capture and initial processing, with data archives that provide a record back to the early 1980s. The spatial resolution of AVHRR is around 1 km. This is relatively poor in comparison to Landsat and other satellite sensors; however, any finer

resolution would produce a large and unmanageable volume of data for global land cover studies (at least for current computing capabilities).

46. While the AVHRR data have been successfully used at the 1 km scale for subcontinental studies of vegetation properties and their temporal changes, the global data set is at present limited to 15-20 km resolution. Thus, there is a considerable potential for greater utilization at scales of ecological relevance. Ways to achieve that potential have recently been reviewed by the Land Cover Working Group of the IGBP Data and Information System, resulting in the following conclusions and recommendations:

a) A global data set of the land surface should be created from the AVHRR data around 1 km resolution, with full global coverage at least once every 10 days for at least a year. Such a data set would be of very great benefit to several IGBP Core Projects, notably GCTE, IGAC, BAHC and GAIM;

b) Substantial effort is required in the pre-processing of the data set (radiometric calibration, atmospheric correction, geometric correction and temporal composing), with several aspects requiring additional research before standard procedures can be established. It can then be determined how best to proceed with continuous monitoring of the Earth, year after year, at this resolution; and

c) A global facility will be required to ensure coordination between ground stations, and the creation of a uniform data set. Such a data set, when converted into information related to the attributes of the vegetation cover, would be of great benefit.

III. THE ROLE OF DEVELOPING COUNTRIES IN IGBP

A. Participation in START

47. So far, there has been only limited participation by scientists in developing countries with regard to international efforts dealing with climate variability and other aspects of global change. Yet their involvement is critical for an effective global scale approach to these problems, as stressed both in a United Nations General Assembly resolution (44/207 of 22 December 1989, "Protection of global climate for present and future generations of mankind") and by the Special Committee on the Participation of Developing Countries of the IPCC. This need is specifically addressed by the global change START of the IGBP, HDP and WCRP. START has initiated a process that will, in the short-term, provide direct assistance to the scientific community to narrow current uncertainties pertaining to global change, and, through stimulating global change research and assessment, also provide necessary information to governmental ministries and agencies involved in current negotiations arising from UNCED. In the long-run, START will lead to substantial capacity building, through the provision of training and education to the next generation of scientists in all countries, with special attention given to the needs of developing countries.

48. Specifically, START will involve the scientific communities within a region by: a) increasing their awareness of the importance of global change issues; b) training them in the multidisciplinary work necessary to implement global change projects; c) helping them to formulate appropriate projects to be carried out in regional or international collaboration; c) assisting them in obtaining adequate technical support to carry out regional interpretation, analysis and modelling through techniques such as remote sensing and the use of Geographic Information Systems; d) promoting collaboration between natural and social scientists on regionally relevant problems; e) providing them with the capability to access and manage appropriate regional databases, and to initiate the establishment of required databases that are not yet available; and f) promoting a dialogue between the scientific community and decision makers, at both national and regional levels.

49. Beneficiaries will also be national governments in the form of Ministries for Environment, Science and Education, Planning and Foreign Affairs, i.e., all those sectors involved in the international negotiations following UNCED, and the development of national responses to associated international agreements. In addition, START provides a mechanism that could be of great value for ministries or agencies for development cooperation, which have an interest in capacity building in the environmental field in developing countries.

50. The IGBP Core Projects and other programme activities benefit component national studies and individual researchers in many ways. The most important overall effect is to maximize scientific progress, at minimum extra cost. Thus a coherent international framework provides "added value" by increasing the productivity of the national effort. The way in which this is achieved varies according to the level of scientific development within a country, and the particular area of study. General benefits are that IGBP:

a) Assists the planning of national global change research programmes by providing a soundly-based, intellectual and organizational framework for focused research, with overall aims, priorities and implementation developed and endorsed by the international scientific community;

b) Adds to the scientific value of component studies, and helps in their interpretation, by providing complementary information; for example, by widening the range of studies, extending their temporal and spatial coverage, and, through inter-comparison exercises, testing models and improving their predictive power;

c) Promotes the rapid communication of scientific ideas and results from the most advance on-going scientific research, through meetings and publications, and by encouraging interdisciplinary liaison at the national, regional and international level between individuals and research groups;

d) Develops, and tests the applicability of, standard methods and protocols for measuring key environmental variables, thereby facilitating national and international quality control, inter calibration studies, and subsequent data exchange, synthesis and interpretation;

e) Assists in the cost-effective deployment of major capital equipment and facilities, by encouraging their collaborative use and efficient scheduling, and promoting the international transfer of technological expertise;

f) Makes available the data sets collected by the component projects and studies of IGBP, and assists in developing common data management strategies, in liaison with national and international data centres;

g) Encourages the full involvement of developing countries, and those with economies in transition, in global change research by promoting the establishment of regional research networks, capacity building through training, and by providing, wherever possible, financial assistance for developing country participation in major IGBP meetings;

h) Keeps the research community informed of developments within the programme through IGBP Reports, the Global Change Newsletter and other publications;

i) Ensures that close working links are developed with other relevant international programmes and projects, particularly those of the WCRP and the HDP, and with international assessment exercises, such as those of the IPCC;

j) Provides the scientific understanding needed for the development and implementation of international conventions and protocols addressing global environment issues; and

k) Promotes the concept of IGBP science, the results obtained from the programme, and their application, to decision-makers, funding agencies and inter-governmental organizations, thereby indirectly assisting in the further financial support of its component studies.

B. Factors that limit the participation of developing countries

51. During the first regional IGBP meeting for South America (São José dos Campos, Brazil, 1990), the following were noted to be factors that limit the more active participation of South American scientists in the disciplines related to the IGBP: a) lack of research funds to start new research projects or continue with existing ones; b) lack of graduate students, collaborators, technicians, etc.; c) over commitment in these research projects or other related teaching, professional and/or administrative duties; d) lack of confidence on the final destination of the results of their research, if they are merged with the worldwide information that will be assimilated into IGBP conclusions; and e) unstable political, labor or research conditions.

52. The economic limitations present in many developing countries have been recognized as the major cause for the lack of increased participation in the IGBP projects. For this reason, not only the search for external funds (i.e. from international organizations, private foundations, and governments of industrialized countries), but any efforts to promote the programme among the governments of the region are highly desirable. This would help scientists to obtain official recognition of the significance of the programme, and the importance of scientific activity for the planning of any local or regional development programmes. Fortunately, there are no serious linguistic or cultural barriers among the countries of the region. However, existing scientific groups in the region are highly sensitive to political and/or economic instability and have a strong tendency to disintegration due to the lack of adequate salaries and stimulation. As a consequence of recurring crises, researchers often leave the region for the more developed countries. The situation in South America is similar to that in other regions.

53. The lack of appropriate mechanisms to recognize creative contributions may prevent some scientists from contributing novel ideas to a project within the scope of the IGBP. Hypotheses and new ideas are the most important resources in science; therefore, scientists may hesitate to contribute ideas in the absence of a clear mechanism to show how their contributions will be recognized. Poor recognition of the IGBP at the national level may limit participation of some scientists, especially those in the institutes with a rigid research agenda.

54. In order to ensure an efficient participation of regional scientists, there is an urgent need to improve communication systems both within the region and with the scientific community outside the region. In addition, due to the lack of sophisticated analytical equipment, computers, etc., in many laboratories in the region, there is a need for the development of strong technological cooperation both within the region as well as with centres outside South America. The Core Projects and National Committees should identify such needs and take appropriate action to remedy the deficiencies.

55. There is an overall lack of scientists and technicians, especially in fields such as atmospheric chemistry and nuclear physics. There is also an absence of adequate training programmes in environmental science at universities and technical high schools. Insufficient library resources constitute another important limitation, as well as problems of acquisition, maintenance, and technology transfer of state-of-the-art equipment and instrumentation that is urgently needed to improve data collection and processing.

56. Some of these concerns were dealt with in later phases of the IGBP programme development (e.g. publication of results, access to databases etc.). Most of these concerns however are valid today and perhaps are typical for developing countries in other regions. Indeed, during the United Nations/International

Astronautical Federation (IAF) Workshop on "Organizing Space Activities in Developing Countries: Resources and Mechanisms" (Graz, Austria, October 1993), similar concerns were expressed. It was therefore agreed that it is extremely important to stimulate the participation of scientists from developing countries by means of: a) research grants; b) travel grants; c) personnel and equipment for research activities; c) scholarships for graduate students; d) access to research centers, data banks, working groups, etc., without financial conditions; and e) specific short-term research contracts.

C. Problems related to the access to environmental data

57. As an increasing number of States invest in ground receiving stations, it is vital that those investments not be rendered obsolete by incompatible new technologies. To this end, Member of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) have emphasized the importance of continuity and complementarity in remote sensing and meteorological satellite programmes. CEOS is the primary international mechanism for coordinating the planning of satellites with environmental applications and the compatibility of data formats. CEOS has been working to increase the dialogue between satellite planners and users including international user organizations, which now have affiliate status in CEOS, particularly with respect to environmental applications.

58. Practical and financial difficulties in gaining access to satellite data for environmental purposes has been a factor limiting the use of satellite data in many countries, particularly the developing countries; Member States of COPUOS have frequently expressed their concern over such high prices. Some actions have been taken to develop flexible pricing arrangements, including lower prices for research use, educational use and archival data. Arrangements are also being made to facilitate acquisition of data through a network of local agents and through electronic means. Recently, the United States National Aeronautics and Space Administration (NASA) has developed a project to this end.

59. NASA and other United States federal agencies maintain vast databases of remote sensing data for Earth and space sciences which have been gathered over the last 30 years. There is a wide range of accessibility to, and cost for the data. Some of these data are on-line and quickly accessible in standard formats at no cost to Internet users. Other data may be stored using old magnetic-tape formats, or may have other significant costs (e.g. from a few hundred to a few thousand US dollars per scene). Data holdings are in many forms and in many places throughout NASA Centers and other facilities. Further, these data holdings grow over time as new types of data are needed and the size of individual data sets continually increases as new data are received on a daily or even hourly basis, e.g. from remote sensing spacecraft. Finally, these data change as the organization of the digital libraries change or as format standards change.

60. For essentially all data, even for data not on-line, users can search an on-line directory, called the Master Directory, to learn what data are available, obtain brief information about them, where and how they may be ordered or accessed, and whom to contact for further information. To keep track of the data holdings, the Master Directory is accessible over Internet. Primarily, the directory identifies the discipline and selective parameters or type of data (e.g. atmospheric chemistry, infrared images, visible images), the time period of observations, and the particular repository or data center where the data can be found. Detailed instructions on the full range of Master Directory capabilities are found in the User's Guide: "Master Directory User's Guide, Alphanumeric Interface," which can be obtained from: NSFC NSSDC/Coordinated Request and User Support Office, CRUSO, Mail Code 633.4, Greenbelt, MD 20771 USA.

61. Most Earth science data are those associated with the Earth Observing System Data and Information System (EOSDIS), and the interagency system called the Global Change and Data Information System (GCDIS). These data include information about atmosphere, land, geology, oceans, and biological entities. Examples of data include chemical, radiation, vegetation, temperature, wind, and ocean height and current. These image-oriented data are organized into data sets, each for a particular type of sensing instrument and

geographic and temporal coverage. The databases are organized and stored at data centers called Distributed Active Archive Centres (DAACs), specializing in specific disciplines. Each data centre has associated scientific users and can provide expert assistance to users of their data holdings. The data provided by EOSDIS include Pathfinder data sets, which consists of long-term remotely sensed data from previous and currently operating satellites. Examples of such data sets are: global vegetation, global sea surface temperatures, global clouds radiation, and aerosols derived mostly from the NOAA and Landsat satellites.

62. The international dissemination of information on the peaceful uses of outer space has been one of the primary concerns of COPUOS since its inception in 1958. The Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) recommended that an international space information service be established within the United Nations Office for Outer Space Affairs (OOSA). This service was to initially consist of a directory of sources of information and data services and would be available to all countries, particularly developing countries. The General Assembly, in resolution 37/90 of 10 December 1982 ("Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space"), endorsed that recommendation, and the Secretariat is working, to develop such a service. Because of the limited resources available, the full implementation of the International Space Information Service (ISIS) programme has been delayed.

63. Each year during the session of the COPUOS its Scientific and Technical Subcommittee, Member States, and particularly the developing countries, discuss the problems related to the non-restricted and non-expensive access to space-related information. To facilitate this process, the existing nucleus of ISIS within OOSA can be substantially expanded in cooperation with and with the support of other organizations. Possible next steps in this expansion could include:

a) Compilation of a list of activities and programmes conducted by different national and/or international organizations and agencies so as to provide a basis for better coordination;

b) Development of a database where data from different Earth observation systems can be obtained. This would help countries with little or no space research activity to gain access to valuable data;

c) Development of a database that will contain information for decision-makers;

d) Investigation of the role which the proposed regional centres for space science and technology education (see below) could play in disseminating and compiling Earth observation data; and

e) Development of databases with information on other space-related subjects, including space communication, meteorology, navigation and basic space science.

64. The further development of ISIS will provide all interested parties with direct access, through the Internet, to all information sources available. ISIS will also facilitate the search and selection of space-related information on behalf of Member States and will provide advice on how such information may best be utilized.

D. The role of the Centres for Space Science and Technology Education

65. While many students, educators and researchers from developing countries now go to developed countries for advanced training and research, such programmes are very expensive and can only accommodate a very limited number of people. A small number of developing countries are developing national educational programmes in space technology and applications, but most countries are not yet in a position to do so. The opportunities for appropriate advanced education at affordable cost for people from developing

countries could be substantially expanded through the establishment of regional educational programmes in developing countries that have the capability to support such programmes.

66. To this end, the United Nations, through OOSA, has begun an initiative to establish Centres for Space Science and Technology Education in each region covered by the United Nations Regional Commissions. The emphasis of the centres on educating educators will provide a multiplier effect to ensure a long-term, adequate supply of trained specialists in the various disciplines required for sustainable development and environmental monitoring .

67. The proposal for the establishment of the regional centres was endorsed by COPUOS in 1990 and subsequently approved by the General Assembly. Consultations have been held with interested countries in the developing regions and with developed countries that might support the centres. Evaluation missions have been undertaken to potential host countries for such centres in Latin America, Africa, Western Asia, Asia and the Pacific. Consultations are continuing to consider how best to establish the centres and ensure their long-term viability in meeting the needs of the countries of each region. During the next four years, INPE of Brazil will be the headquarters for the regional Centre for Space Science and Technology Education in Latin America and the Caribbean, which will be rotated every four years between Brazil and Mexico.

68. In the initial phase the centres will concentrate on providing an advanced education, research and applications development programme in remote sensing, satellite meteorology and geographic information systems. Improving data processing and information management capabilities in developing countries including archives of satellite data and links to international environmental databases such as UNEP's Global Resource Information Database (GRID), will be an important element of the centre's functions. The centres will therefore make a major contribution to meeting the need (as identified in Agenda 21 of UNCED) to develop the capacities of developing countries to participate effectively in the global effort to protect the environment and ensure the sustainable development of all countries.

69. In the area of Earth observation systems, for example, the programme of each regional Centre will:

a) Develop skills and knowledge of university educators, environmental research scientists and project personnel in remote sensing and related technologies for subsequent application in national development and environmental management programmes;

b) Assist educators to develop environmental and atmospheric sciences curricula that they can use to advance the knowledge of their students in their respective institutions/countries;

c) Develop the skills of environmental research scientists and project personnel in the design, development and application of remote sensing techniques in natural resources management and biodiversity protection;

d) Assist research scientists and project personnel in preparing space-derived information for presentation to the policy and decision makers in charge of national and regional development programmes;

e) Enhance regional and international cooperation in space science and technology programmes, particularly those that are related to environmental monitoring and natural resources management, and support and contribute to the work of institutions of higher learning in each region and the activities of national/regional remote sensing user assistance and training centres; and

f) Assist in disseminating to the general public, the value of space science and technology in improving their everyday quality of life.

70. In each region, the Centre will prepare and carry out annual education, research and applications programmes for university level educators and research and application scientists drawn from the user communities. The duration of each programme would be for a period of nine months. Experts and consultants contributing to the Programme will be highly qualified (scientific and technical) individuals from the countries of the region.

71. The programmes will focus on teaching techniques and methods in environmental information systems as applied to educational, environmental and economic development issues. Case studies using remote sensing and meteorological satellite data that can be processed, analyzed and stored on micro-computer systems will be prepared in advance to provide "hands-on" illustrations of applications to specific natural resource surveys and to specific environmental monitoring and assessment exercises.

72. Participants also will acquire knowledge and skills needed to develop and prepare teaching manuals, auxiliary audio visual materials, research and applications project proposals and reports. During the school vacation periods, two workshops for secondary and primary schoolteachers, each lasting a minimum period of two-weeks, will be organized on an annual basis. Participants in these workshops would be shown the relevance of remote sensing technology and other aspects of Earth observation systems to national development and environmental monitoring, and to the means and materials through which they could introduce these concepts into the secondary education curricula of their countries.

73. An integral part of each of these Centres for Space Science and Technology Education will be a Data Management Unit. Through this Unit, each Centre will have direct linkages with existing relevant global data centres and the nearest UNEP/GRID Centres. Such linkages will enable those participating in the programmes of these Centres to utilize the data in the archives of the data centres, particularly when they undertake projects that can benefit from their gaining such an access. Each Centre will have direct access to the Mercure satellite-based communications network proposed by European industry and ESA for the benefit of UNEP. The Mercure network would provide a modern, state-of-the-art global communication capability for the transfer of environmental data between different UNEP/GRID Centres and between databases and archives and users of environmental data.

74. The technical standards of the proposed network would match those of local G.Ss, used to analyze and process environmental data, with the capability to support computer file transfers, i.e. file transfer protocol (FTP), document transmission, voice communication, and video transmission including video-conferencing. The network would provide the Centres with timely access to environmental data including maps and images acquired from environmental satellites. Other important data made available through the Mercure network would concern environmentally-sound technologies and methods to safeguard the World's renewable resources. The network would also contribute to the development of better communication between regional Centres and could help to establish global teleconference sessions in order "to bring together" participants/instructors from all regional Centres to discuss important programme elements or to share practical experience.

75. Each Centre will also be equipped with an AVHRR receiving station. In addition, each Centre will be linked with the nearest Earth observation ground receiving station(s). The data collected from these stations will be used in the activities of each Centre and when deemed necessary, will also be part of the Centre's archives. Each Centre will establish a data management programme for the purpose of enhancing the skills of its user community in order that this community could have the capability to: a) develop guidelines for data collection; b) standardize their physical and socio-economic data collection process; c) develop guidelines for data geo-referencing; d) undertake the integration of socio-economic and bio-physical data through GIS; e) establish up-to-date national baseline information; and f) organize continuing education activities for policy/decision makers on the importance of data and its value and relevance in decision making.

76. Each of these regional Centres will be established in a major national science and technology-oriented university or research institution. Such an arrangement will enable the Centres to optimally utilize the existing professional staff and physical infrastructure at the host institution. The participants in the programmes of the Centres will also be able to collaborate with the graduates of existing training and user assistance centres on major research and application projects for the benefit of their countries. The establishment of the regional centres will require a strong commitment of support from the host countries as well as technical and financial assistance from developed countries and international organizations. Such assistance could take the form of full- or part-time technical specialists, data processing equipment and software, satellite data, funding for scholarships and other human, technical and financial resources.

IV. CONCLUSIONS

77. Now that IGBP research is well underway, greater emphasis needs to be given to coordination, time-scheduling and data management, and to ensuring that the necessary resources are secured for the core research that is essential for the attainment of the programme's long-term, global goals. IGBP research, primarily funded at the national level, involves several thousand scientists in over sixty countries. The international guidance for their work is provided by the SC-IGBP and its Secretariat, primarily acting through the SSCs, Standing Committees and CPOs of the programme's component projects. This organizational structure has a catalytic role, and is closely involved in the interpretation, synthesis, assessment and communication of results.

78. The importance of the IGBP initiative and its achievements to date have been widely acknowledged and formally recognized at both the governmental and intergovernmental level. Its main work phase, with all established Core Projects operational, is just beginning. However, existing support is inadequate for full implementation. For that to be achieved, there must now be a long-term commitment to support both the research and its international infrastructure. The lack of funding for either component would seriously jeopardize the success of the programme.

79. Three-fifths of the land area and nearly all of the rich and varied tropical regions of the globe, which are also the repository of the bulk of global genetic diversity, are occupied by developing countries. They have the privilege and responsibility to study and understand this global environment scientifically. The applications and benefits from such a understanding are immediate and immeasurable.

80. Recognizing that developing countries are the most vulnerable to the impact of global changes both in terms of economics and human welfare, and recognizing that IGBP provides a unique opportunity for developing countries to build an expert and self-reliant capacity in the interdisciplinary field of basic sciences, environment and development, all developing countries are encouraged to join IGBP and participate in it. There must be a national commitment to the programme and at least modest resources made available to their scientists. It is, however, the responsibility of scientists from developing countries to ensure that the decision makers in their respective countries are made aware of the potential benefits of the IGBP and that support of these activities is in their overall national interest.

81. In view of the objectives and intrinsic scientific content of IGBP, as well as its intensely interdisciplinary nature, training has become a decisive element. It covers different levels: researchers, technicians, and managers. It requires training opportunities at the national, regional and international levels; and it involves different scientific areas, core projects, techniques and methods.

82. An important requirement of IGBP activities is a scientific and studied utilization of remote sensing data for a wide variety of purposes. To do this effectively, scientists from developing countries will require

suitable training, access to data (preferably free of charge), and opportunities for regional and global cooperation.

83. To facilitate the process of increasing the participation of developing countries in the IGBP programme, as well as in other programmes and projects involving space research and applications, the United Nations Committee on the Peaceful Uses of Outer Space and its subsidiary bodies should make specific recommendations, based on their deliberations. COPUOS may wish, for example, to recommend the extension of the International Space Information Service of the Secretariat to better serve the need for coordinating and expediting access to environmental data bases and other sources of information. Similarly, the role of the proposed Centres for Space Science and Technology Education in assisting IGBP activities of developing countries should be explored in more detail.

LIST OF ACRONYMS

ACE - Advisory Committee on the Environment
AMBIANCE - Amazon Ecology and Atmospheric Chemistry Experiment
APN -Asia-Pacific Network for Global Change Research
ASEAN - Association of Southeast Asian Nations
AVHRR - Advanced Very High Resolution Radiometer
BAHC - Biospheric Aspects of the Hydrological Cycle (of IGBP)
BAKOSURTANAL - National Coordinator for Survey and Mapping Agency (of Indonesia)
BATERISTA - Biosphere-Atmosphere Transfers and Ecological Research In situ Studies
BMG - Meteorological and Geophysical Agency (of Indonesia)
ENSO - El-Niño Southern Oscillation
CEOS - Committee on Earth Observation Satellites
CGCR - Committee on Global Change Research (in the United States)
COPUOS - Committee on the Peaceful Uses of Outer Space (of United Nations)
CPO - Core Project Office (of IGBP)
DCP - Data Collection Platform
ENRICH - European Network for Research in Global Change
EOS - Earth Observing System
EOS-DIS - EOS Data and Information System
ERS - European Remote Sensing Satellite
FAO - Food and Agriculture Organization
FCCC - Framework Convention on Climate Change
GAIM - Global Analysis, Interpretation and Modelling
GAW - Global Atmosphere Watch
GCDIS - Global Change Data and Information System
GCOS - Global Climate Observing System
GCTE - Global Change and Terrestrial Ecosystems (of IGBP)
GEMS - Global Environment Monitoring System
GEWEX - Global Energy and Water Experiment
GIS - Geographical Information System
GLOCHANT - Global Change and the Antarctic
GOES - Geostationary Operational Environmental Satellite (of NOAA)
GOEZS - Global Ocean Euphotic Zone Study (of IGBP)
GOOS - Global Ocean Observing System
GRID - Global Resource Information Database (of UNEP)
GTOS - Global Terrestrial Observing System
HDP - Human Dimensions Programme (of Global Environmental Change Programme)
HRPT - High Resolution Picture Transmission
IAI - Inter-American Institute for Global Change Research
IAF - International Astronautical Federation
ICACGP - International Commission on Atmospheric Chemistry and Global Pollution
ICSU - International Council of Scientific Unions
IGAC - International Global Atmospheric Chemistry Project (of IGBP)
IGBP - International Geosphere-Biosphere Programme
IGBP-DIS - IGBP Data and Information System
IGFA - International Group of Funding Agencies
IOC - Intergovernmental Oceanographic Commission (of UNESCO)
IPCC - Intergovernmental Panel on Climate Change
IRS - Indian Remote Sensing Satellite
ISIS - International Space Information Service

ISRO - Indian Space Research Organization
ISSC - International Social Sciences Council
JERS - Japanese Earth Resources Satellite
JGOFS - Joint Global Ocean Flux Study (of IGBP)
LAMBADA - Large-scale Atmospheric Moisture Balance of Amazonia using Data Assimilation
LANDSAT - Land Remote Sensing Satellite
LAPAN - National Aeronautic and Space Agency (of Indonesia)
LOICZ - Land-Ocean Interaction in Coastal Zone (of IGBP)
LUCC - Land Use/Cover Change (of IGBP)
MOS - Marine Observation Satellite (of Japan)
MST - Ministry of Science and Technology (of India)
NATT - Northern Australia Tropical Transect
NC - National IGBP Committee
NOAA - National Oceanic and Atmospheric Administration (USA)
NRC - National Research Council (United States)
OOSA - Office for Outer Space Affairs (of the United Nations Secretariat)
PAGES - Past Global Changes (of IGBP)
SAC - Scientific Advisory Council (of IGBP)
SARCS - Southeast Asian Regional Committee for START
SLR - Sea Level Rise
SC-IGBP - Scientific Committee for the IGBP
SCAR - Scientific Committee on Antarctic Research) (of ICSU)
SCOPE - Scientific Committee on Problems of Environment (of ICSU)
SCOR - Scientific Committee on Oceanic Research
SPARC - Stratospheric Processes and their Role in Climate
SPOT - System Probatoire d'Observation de la Terre (French remote sensing satellite)
SRAVAN - Society for Relief Avoidance and Vigilance Against Natural Disaster (Bangladesh)
SSC - Scientific Steering Committee (for GCTE of IGBP)
START - System for Analysis, Research and Training (of Global Change, IGBP)
TEACOM - Regional Committee for Temperate East Asia (of START)
UNCED - United Nations Conference on Environment and Development
UNEP - United Nations Environment Programme
UNESCO - United Nations Education, Science and Cultural Organization
VHRR - Very High Resolution Radiometer
WCRP - World Climate Research Programme (of ICSU)
WMO - World Meteorological Organization
WWW - World Weather Watch

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UNITED NATIONS

GENERAL ASSEMBLY

Distr.
GENERAL

A/AC.105/591
9 December 1994

ORIGINAL: ENGLISH

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

SATELLITE-BASED RADIO BROADCASTING

Note by the Secretariat

1. The Working Group of the Whole to Evaluate the Implementation of the Recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), at its eighth session (A/AC.105/571, annex II, para. 17), recommended that several studies on space applications should be carried out to demonstrate the potential of space technology. The Working Group of the Whole identified a number of possible subjects for such studies, including the use of satellite-based radio broadcasting services.

2. The report of the Working Group of the Whole was adopted by the Scientific and Technical Subcommittee at its thirty-first (1994) session (A/AC.105/571, para. 22), and the recommendations contained in the report were endorsed by the Committee on the Peaceful Uses of Outer Space at its thirty-seventh session and by the General Assembly in its resolution 49/34 of 9 December 1994.

3. In response to the request of the Working Group of the Whole, the Secretariat has prepared the present study. The purpose of the study is to provide a review on the applications of satellite-based radio broadcasting services, primarily for the benefit of countries that have not yet used that technology but are interested in its potential benefits. The study was prepared using a variety of national and international sources, which are listed in the selected bibliography (see annex). A summary of the study is provided below. The study, which is available in English only, is presented in the annex to the present note.

SUMMARY OF THE STUDY

4. Existing radio broadcasting systems have many deficiencies. Amplitude modulated (AM) radio suffers from bandwidth limitations, interference from other stations, especially at night, and electrical interference from power lines, machinery and household appliances. Frequency modulated (FM) radio was planned and designed in the 1950s to deliver high-quality sound to fixed receivers. It was not designed for portable or mobile use. The advent of cheap portable receivers and the marketing advantages resulting from providing FM radio in cars has changed listening habits and needs. Unfortunately, FM radio suffers from multi-path interference and other effects when used in portable and mobile environments.

5. Both AM and FM radio fail to offer uniform technical quality throughout their intended coverage areas. The present AM and FM broadcasting systems have used the frequency spectrum inefficiently and restrict the development of new services. Digital broadcasting will be widespread before the end of the century. It is believed that ultimately a global international standard will be developed and introduced. Such a standard will allow the use of common frequency bands and therefore enable the development of a universally

compatible and inexpensive receiver. Recent developments in satellite technology now make it feasible for portable and mobile radios to receive transmissions directly from satellites in the geostationary orbit.

6. For this reason, there has been much interest expressed about those systems among the various satellites projects designed to provide different types of services that are now under development that will provide country-wide broadcasting of radio and television programming. Although satellite sound broadcasting has been discussed for over 20 years, it is only recently that technological developments have rendered this concept practical. The possibility of using satellites to transmit television signals has prompted reflection on their use for sound broadcasting as well. Satellite sound broadcasting is a replacement technology for terrestrial radio broadcasting systems. The key differences in technology between terrestrial and satellite radio broadcasting systems relate to coverage, fidelity and convenience.

7. Satellite sound broadcasting involves the transmission of audio and auxiliary data transmissions directly from a satellite to low-cost receivers with semi-omnidirectional antennas. The audio programming is up-linked to the satellite from various locations, usually near the studios of a terrestrial radio station. Direct rebroadcasting of the audio programming via satellite greatly increases the coverage area of a radio station, while eliminating the need to use large amounts of kilowatts of power for broadcasting. Where the satellite line-of-sight is permanently obstructed, for example in tunnels, it can be complemented by a terrestrial transmitter operating on the same frequency. Such a hybrid satellite-terrestrial system can easily be implemented using digital techniques and is economical.

8. All current satellite sound broadcasting projects are planning for the audio fidelity associated with either FM radio or compact disc recordings. It is generally accepted that satellite sound broadcasting provides an economic means of covering large areas with a radio signal. Current digital satellite radio projects have per channel costs that compare favourably to those of major international shortwave broadcasters. Improved audio fidelity is planned for satellite sound broadcasting to encourage consumers to purchase the new satellite radios, in addition to providing more reliable signal reception across large geographical distances. However, there are currently over 2 billion radios in use (nearly half of them in the developing countries), more than the number of telephones and television sets combined, and only successful penetration of such a large potential customer base will ensure the economies of scale needed to reduce the costs of digital radios to the current level of analogue radios.

9. Digital audio broadcasting technology has sought to meet broader needs than analogue broadcasting. These include the capability of providing radio service to remote, rural and developing regions where the terrestrial infrastructure does not exist or cannot be economically or readily provided; the capability of providing high-quality reception to portable or car radios; spectrum efficiency to overcome the problems of spectrum congestion and the limited availability of services; and the capability of being power efficient, especially to meet the needs of the satellite transmission systems. Indeed, while countries such as the United States of America enjoy an average of 30 radio channels per million persons, most countries in the world have an average of only two channels per million persons. Developing countries are likely to see this technology as an economical means of delivering broadcasting services which have, to date, been expensive and slow to develop. In more developed countries, terrestrial digital sound broadcasting might also be an attractive alternative to existing AM and FM sound technologies.

10. The 1992 World Administrative Radio Conference (WARC) paved the way for satellite radio broadcasting. In comparative terms, the new radio broadcasting service received an amount of electromagnetic spectrum nearly twice as large as all previous radio broadcasting allocations combined. When considering the appropriate allocations to satellite sound broadcasting, it was taken into account that this service has a unique ability to help facilitate national development. As a broadcasting service, it is capable of providing a country's entire population with access to vital health, education and weather information.

11. Similarly, the first World Telecommunication Development Conference, held by the International Telecommunication Union at Buenos Aires, from 21 to 29 March 1994, declared that development strategies should encompass sound and television broadcasting via terrestrial and satellite systems as one of the key factors in promoting social and cultural development and that the broadcasting technologies being developed would provide opportunities, including those of distance learning, for a greater contribution to development.

12. Many large countries still have large rural tracts with little or no radio service other than unreliable high-frequency (HF) services. Due to poor road infrastructure, millions of persons in newly developed countries often have to commute for several hours and are sometimes delayed in heavy traffic during which time they tune in to radio. Burgeoning personal automobile markets in these countries will provide a high demand for satellite digital audio. Hence, the satellite sound broadcasting service represents the first stage of national telecommunications development: that of regularly providing a nationwide radio communication service with meaningful programming. A satellite sound broadcasting system should also include an auxiliary data capability to enable services such as nationwide paging via satellite. For many developing countries, satellite sound broadcasting represents the only practical way in which to establish the kind of nationwide paging services currently enjoyed in some developed countries.

13. Telecommunications in general, and satellite sound broadcasting projects in particular, are capital-intensive activities that require ongoing investment to expand and modernize the service. The majority of telecommunications capital spending is currently taking place in developed countries. For instance, of an estimated US$125 billion spent on telecommunications in 1992, roughly 80 per cent was in high-income countries. Clearly, the developing countries will have to invest more resources if the telecommunication gap is to be reduced. The problem is not strictly a shortage of money – practically every telecommunications operator in the world is profitable – but rather one of national priorities and the relative importance afforded to telecommunications.

14. The international satellite industry has historically been highly regulated. Recent changes in the telecommunication sector have spilled over into the satellite industry. The result has been changes in national satellite policies, the policies of the International Telecommunications Satellite Organization (INTELSAT), as well as the introduction of private satellite systems. The resulting competition has produced growth and innovation in services, smaller and more flexible earth stations and lower prices. To implement a satellite network it is necessary not only to have the financial and technological capability to launch a satellite, but also to obtain an orbit position that would adequately serve the target area and to coordinate the frequency assignment to avoid interference with other satellite radio signals. The developing countries' concerns over accessibility are based on the natural limitations of the geostationary orbit and frequency spectrum.

15. There are many important international, regional and national satellite digital audio broadcasting (DAB) systems, services, projects and programmes currently being developed, including WorldSpace and INDOSTAR, to introduce services into the developing countries, the INTELSAT Digital Audio Distribution (DAD) system, as well as the systems being developed by the Satellite CD Radio, American Mobile Radio Corporation, Primosphere Limited Partnership, Digital Satellite Broadcasting Corporation and the European Space Agency (ESA). A relevant terrestrial project, the Eureka 147 programme, is also under development by a consortium of European companies. The above-mentioned projects are briefly described in the annex to the present note.

Annex

SATELLITE-BASED RADIO BROADCASTING

Study by the Secretariat*

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*The present study has not been edited. Mention of firm names and commercial products does not imply the endorsement of the United Nations.

INTRODUCTION

A. Satellite communications and broadcasting for development

1. Information is becoming an increasingly important global asset. Information is the primary driving force in the accelerated development of both industrialized and developing nations. It helps to create new markets and jobs and to improve national efficiency and productivity. Expansion of this process is highly dependant on the spread of information-related technologies. It is no longer possible for a nation or a region to embark on a development programme without the support of a modern telecommunications infrastructure. Yet, as in the past, some national governments remain reluctant to take the steps necessary to implement the technological infrastructure development needed to take advantage of modern communications technologies. In this sense, many outdated policies and attitudes remain an impediment to the technological development of countries.

2. Some governments of industrialized countries have committed themselves to changing the role that governments play in the information revolution. This has led to initial work on the establishment of national information infrastructures which will seek to combine computer networks, databases and consumer electronics into a single infrastructure capable of delivering to its users tremendous amounts of information. An integral part of these infrastructures will be the highly-trained personnel that will be needed to build, maintain, and operate the various sub-systems that will comprise the overall communications infrastructure. The ultimate goal of the planners of these national systems will be convergence of the national information infrastructures into one global infrastructure serving the entire international community.

3. Many developing countries find that, while basic services should remain in the governmental sector, rapid technological development compels them to provide value-added services through the private sector. This has led to a wave of deregulation of the postal, telephone and telegraph (PTT) organizations in many developing countries. Yet, without modern infrastructure, developing countries cannot attract the foreign investment or loan capital from international lending institutions that is often necessary for private sector industrial development. International telecommunications networks are largely a collective, cooperative and pragmatic process, even though there is fierce competition for the provision of services and equipment. The transfer of telecommunications technology involves contentious issues of standardization of equipment and protocols for interconnectivity, as well as problems of bandwidth allocation, and equitable access to information. All these issues have significant social and economic ramifications. Central to this process of technology transfer is the convergence of computer and telecommunications technologies.

4. Of all the new telecommunications technologies, satellites have the potential to make the greatest impact on the distribution of information. Satellite communication systems can make communications truly universal, even reaching the most inhospitable parts of the world. Satellites are and will continue to be an essential element of the growing and improving communications infrastructure. This is because satellites possess the following characteristics: ubiquity, mobility, distance insensitivity, and resiliency.

5. As a result of these unique features, satellites already play an essential role in global communications, providing video, data and audio services to locations that are not covered or cannot be reached by terrestrial communications. Even with the emergence of underwater fibre-optic cables, satellites still carry about 50 per cent of all international communications traffic. They are the input source to most terrestrial TV distribution networks.

6. Via satellites, rural and remote schools have access to up-to-date information, delivered by the best professionals in the field. In a rapidly changing world, where a well-educated workforce and lifelong education are essential to economic strength, the importance of accessible and affordable information and

communications tools are of paramount importance. New technologies, such as advanced simulation and training, tele-presence, and virtual reality, can facilitate education. These technologies will also create continually increasing demands on our telecommunications infrastructure.

7. In business, satellites have made it possible for corporations to cooperate efficiently almost everywhere on Earth. Information and communication technologies have become instrumental in virtually every business and are used for product development, manufacturing, marketing, sales and service. These new technologies have helped to improve productivity and increase innovation in almost every sector of the world economy.

8. Health care is another area where satellites will play a critical role in the future. New communications and information applications will allow: on-line patient records; remote diagnosis; and advanced medical analysis and simulation.

9. The satellite communications industry is beginning to aggressively pursue its role in the emerging national information infrastructures. Among the many projects currently under development that will utilize satellites to provide different services, there are several that will utilize satellites for direct, country-wide radio and television broadcasting. Notwithstanding the progress that has been made in recent years, the satellite communications industry must become more active in the development of standards and protocols that will govern the future architecture of the information infrastructure. A number of technical and regulatory issues still need to be resolved if the vision of an integrated information infrastructure is to be achieved.

B. Digital Broadcasting

10. Existing radio broadcasting systems have many deficiencies. AM radio suffers from bandwidth limitations, interference from other stations, especially at night, and electrical interference from power lines, machinery and household appliances. FM radio was planned and designed in the 1950s to deliver high-quality sound to fixed receivers. It was not designed for portable and mobile use. The advent of cheap portable receivers and the marketing advantages resulting from providing FM radio in cars has changed our listening habits and needs. Unfortunately, FM radio suffers from severe multi-path interference and other effects when used in portable and mobile environments.

11. In terms of coverage, both FM and AM radio fail to offer uniform technical quality throughout their intended coverage areas. The geographical limit of coverage is extremely poorly defined. This leads to audience dissatisfaction and poor spectrum efficiency. The present AM and FM broadcasting systems have used the frequency spectrum inefficiently and restrict the development of new services. There simply is not sufficient room for new stations in the larger markets. One of the primary objectives of the new broadcasting services is to encourage a wider range of these, particularly open narrow-casting services. For these systems to succeed, they will need to broadcast on the same bands as other broadcasters so that they can be received by normal radio receivers.

12. Digital broadcasting will be widespread before the end of the century. It is believed that ultimately a global international standard will be introduced that will allow the use of common frequency bands and therefore enable the development of a universally compatible and inexpensive receiver. Digital technology has already become the standard for electronic communication and there are several reasons why radio broadcasting is also likely to be digitized. The rapid replacement of the vinyl record market by compact discs shows that users want digital technology and sound quality. Similarly, Mini Discs and Digital Compact Cassettes are taking over the market of analogue cassettes. Many broadcasters are already using digital technology within their studios and for communications with other stations and for outside broadcasts.

13. Because digital broadcasting systems are not compatible with current broadcasting systems, a new receiver will have to be developed that is capable of receiving digital programming. Despite this hurdle, digital broadcasting systems offer the possibility to fundamentally change all broadcast media by offering multi-channel, multimedia, and other high-quality features that consumers are increasingly demanding. In this context, it will be important for manufacturers to develop and produce systems that will be able to provide the services consumers want at a cost they can afford.

14. The digitalization of broadcasting systems does not only involve the switch from an analogue system to a digital system, but also offers the possibility of radically changing programme production techniques and integration of information reception and processing. Digital technology has already been introduced into the broadcasting field and is now used in studio equipment, TV receivers, video tape recorders and other equipment. Digital technology is also used for broadcasting the PCM sound of the digital sub-carrier/NTSC system, teletext, and FM multiplexing. The signals of these broadcast systems are multiplexed with the analogue signal of the main services, but systems that use dedicated digital channels are now being developed.

15. Recently, there has been significant progress in the development of highly-efficient audio and video encoding technology for use in communications and electronic products. Such technology, particularly when utilized for the digital transmission of television signals, increases the efficiency of frequency utilization. This has occurred in tandem with society's growing need for new information technologies and has, in turn, prompted the development of new types of data services and data broadcasting systems. One of these new systems, Integrated Services Digital Broadcasting (ISDB), has been developed as a broadcasting system to digitally integrate information such as television, sound and data in order to flexibly provide various kinds of services. ISDB will have several advantages if it is fully developed into a new broadcasting infrastructure, including efficient frequency utilization, its ability to accommodate many different service broadcasters and to supply new services suited to user demand.

16. ISDB will benefit from the overall advantages of digitalized broadcast production, signal transmission and reception. Digital production equipment for news-gathering and digital studio facilities, connected by digital lines, will result in a more efficient production environment. Digital signal transmission technology will also allow broadcasters to offer more channels, providing a diverse array of services. Information provided by these services will be sent to homes without quality deterioration through a single integrated receiver. By integrating circuits in large-scale integrated circuits, small, low-cost receivers can easily be produced.

17. There are many possible ways in which ISDB signals can be transmitted, including via 22 GHz, 12 GHz, and 2.5 GHz satellite channels, terrestrial channels and optical fibre cables. Among these, the satellite broadcasting channels in the 12 GHz-band have the most potential. It must be noted that when a broadcasting signal is transmitted by digital modulation techniques and using only one satellite broadcasting channel, the interference protection ratio used in WARC planning, which dictates that no interference can be detected in the same channel, must be adhered to.

18. Digital compression techniques have improved sound quality so much that it is now possible for radio signals to be broadcast from a living room, a sports stadium or a restaurant with excellent sound quality. The sound heard by radio listeners often travels over telephone lines. This has been made possible by two parallel developments. First, to encourage private industry to use Integrated Digital Services Networks (IDSN) systems to carry digital signals between computers, video conference cameras and high-speed fax machines, some telecommunication operators now charge the same rates for digital calls and analogue calls. Second, the electronic industry has built coders that convert studio quality analogue sounds into digital code and compress it into a data stream which can be sent through IDSN networks with no discernible loss of quality.

Conventional twisted-pair telephone lines carry an analogue audio signal with a bandwidth of less than 4 KHz, giving a "boxy" sound when replayed on the radio. An IDSN line, on the other hand, carries two separate digital data streams, each running at 64 Kbit/s, which therefore results in better sound quality.

I. Technical, economic and regulatory aspects of digital broadcasting by satellite

19. Although audio broadcasting via satellite has been discussed for over 20 years, it is only recently that the technology has matured to the point where the concept is practical. New technological developments in audio broadcasting are aimed at improving the efficiency of conventional services through a more rational and cost-effective use of existing resources (frequency bands, equipment and networks), and the introduction of new services.

20. Consideration has been given to the possibility of using a whole television channel to transmit a multiplex of stereo programmes or to use the sound/data time multiplex element of a Multiplexed Analogue Component (MAC) television channel to transmit independent sound programmes. Such systems would require fixed reception equipment and would always be linked to television systems. Accordingly, following studies carried out by the European Broadcasting Union (EBU), the Consultative Committee of International Radio Communications (CCIR) has contemplated the possibility of introducing satellite sound broadcasting in the 0.5-3 GHz frequency band using stationary, portable or mobile receivers. (This possibility had also been considered by the 1979 WARC, as well as the ORB-85 and ORB-88 conferences which were special sessions of the WARC on the use of the geostationary satellite orbit and the space services utilizing it.)

21. Satellite audio broadcasting systems could economically cover vast areas, thereby providing total coverage of a whole country, with a constant reception quality and a vast choice of programmes. The sound quality would be comparable to that obtained by other digital sound reproduction equipment such as compact disc players.

22. Consideration is also being given to the development of a low-cost FM system capable of using existing FM receivers. These are particularly suitable for use in countries at low latitudes where there is virtually no signal attenuation due to signal blocking. Simple digital systems could also be economical, in particular for monophonic broadcasts. More advance receivers may be needed for use in large towns, especially those at higher altitudes, where reflection and absorption occur more frequently.

23. Satellite audio broadcasting would replace existing terrestrial radio broadcasting systems, including short wave radio (high frequency band, 3-30 MHz), long wave radio (AM band, 0.5-1.5 MHz), and medium wave radio (FM band, 88-108 MHz). The key differences among these radio broadcasting systems relate to coverage, fidelity, and convenience. Satellite audio broadcasting is functionally similar to short wave and AM radio in that it is designed to cover very large geographical areas, such as whole countries or continents. However, a satellite audio broadcasting system would accomplish its coverage with direct, line-of-sight connections between user radios and the satellite, whereas a short wave radio broadcasting system achieves coverage via ground-wave and sky-wave propagations. A satellite transmitter requires only about 50 W of solar panel power to achieve the same radio coverage as a standard 500 KW ground-based short wave transmitter.

24. Satellite sound broadcasting differs from shortwave and AM systems in that it is being developed to serve as a high-quality audio medium. Although satellite sound broadcasting need not be digitally modulated, all current projects anticipate digital modulation to enable the sophisticated coding schemes needed to permit low-gain, mobile receiving antennas. Although digital modulation does not by itself provide an improvement in audio fidelity compared to that available over short wave or AM radio systems, all current satellite sound broadcasting projects are being designed to provide the level of audio fidelity associated with FM radio and

compact disc recordings. This high level of audio fidelity is being planned for satellite sound broadcasting systems as a way to encourage consumers to purchase the new satellite radios.

25. Satellites have been used for many years to transmit radio programming across large areas for reception by large terrestrial antennas and subsequent re-transmission by ground transmitters. But, satellite radio broadcasting to audiences in mobile vehicles was not possible because the satellite power received on the ground was never strong enough to be received by a portable or mobile radio equipped with an omnidirectional antenna.

26. Satellite sound broadcasting represents the culmination of 30 years' effort to reduce the size of satellite receiving terminals. Spread-spectrum satellite data networks developed in the 1980s paved the way for development of mobile satellite navigation and portable satellite sound broadcasting systems in the 1990s. It is now economically practical to provide much of the signal gain (about 20 dbs) generally offered by satellite ground antennas.

27. The ratio of satellite power to downlink frequency has increased due to higher-power satellite transmitters and new frequency allocations in the lower microwave region between 1.4 and 3.6 GHz. This reduces the amount of antenna gain needed to receive a satellite radio signal from what was required with earlier point-to-multipoint satellite radio redistribution systems. This is due to the inverse-square relationship between wavelength and the necessary transmission power for a given received power flux density on the surface of the Earth. Finally, the need for directive satellite ground antennas has been reduced by sophisticated coding techniques. This minimizes the necessary data rate that must be decoded by the satellite radio receiver, thus improving the efficiency of the system.

28. Satellite sound broadcasting techniques have also been developed to deal with the variable fading characteristics of a mobile channel. In traditional satellite communications systems, variable fading arises only from rain, and the terrestrial receiving stations are sized appropriately to compensate for rain losses with built-in margin (greater gain). But with satellite sound broadcasting systems, the quality of free-space channel between a radio receiver and the satellite can change almost constantly and unpredictably, as in the case, for example, of a satellite radio-equipped car passing by buildings, trees and other line-of-sight obstructions.

29. There are three satellite sound broadcasting techniques to mitigate the variable fading characteristics of a mobile channel: space diversity, time diversity, and frequency diversity. The common element in each of these techniques is a reliance on the fact that mobile-link fades occur differentially in space, time and frequency. For example, by spreading a source signal among several frequencies, a signal loss at any particular frequency need not be perceptible to the listener because the radio still receives the major portion of the signal at the other frequencies. Similarly, a source signal can be divided randomly in many microsecond-level time blocks. Fades that affect some time blocks need not be perceptible to the listener so long as most of the time blocks are not affected. The most effective satellite sound broadcasting anti-fading techniques combine frequency and time diversity. Space diversity requires multiple antennas, a feature that to date has limited its attractiveness among system developers.

30. Current audio source coding technology allows the following correlations to be made between satellite sound broadcasting rates and audio fidelity: 256 Kbit/s: stereo compact disc quality; 64 Kbit/s: monophonic FM-radio quality; and 32 Kbit/s: monophonic AM-radio quality. Generally, satellite sound broadcasting projects targeted at Europe, North America, and Japan are being designed for compact disc quality. Satellite sound broadcasting systems for developing countries are being designed to operate at 64 kbit/s to enable a qualitative fidelity upgrade from short wave radio, while reducing satellite power requirements (and hence cost) by a factor of four compared to the 256 kbit/s compact disc-oriented systems.

31. Some specialists argue that if these types of systems are to be introduced in developing countries, there must be good prospects for them to remain in service for many years. The systems that are currently only in the research and development phase, such as direct digital audio broadcasting systems, should be avoided by developing countries. These countries should instead rely on established satellite providers such as INTELSAT, INMARSAT and EUTELSAT to provide the space segment for radio broadcast systems. With regard to the terrestrial element of radio sound delivery systems, serious consideration should be given to improving programming delivery, both in extent and content, to fixed installations and local rebroadcasting capabilities. This would ensure that the existing receivers could be used to provide improved reception quality. Should direct satellite reception become available, it could be introduced progressively once it became clear that the system would continue operation and that reasonably priced reception equipment would be available.

32. Opponents of DAB systems consider it unlikely that any significant proportion of the new digital receivers will be manufactured in developing countries in the first few years after such systems become operational. On the other hand, because the technology required for manufacture of receiving equipment for existing satellite broadcasting systems is relatively mature, it is possible that developing countries will become involved in the manufacture of these items. Developing countries would also be able to insert locally-produced programming through local receiving and distribution stations.

33. Satellite sound broadcasting radio receivers are being designed to be much more convenient to use than the short wave systems they will replace. Tuning of the new satellite digital radios will be accomplished by arbitrary channel numbers rather than by kilohertz or megahertz designations. This is because the digital radio broadcasting systems will be able to reassign radio frequencies to different channel numbers, and command all radios to display the currently appropriate channel number for each frequency. Each broadcast will also include digital information regarding the programme name and format. The new digital radios will be able to display these names, thereby enabling listeners to tune into the desired programme using this textual information. Finally, the new radios will be individually addressable via a unique, built-in identification code. This feature will enable each digital radio to also serve as an alphanumeric paging terminal and as a receiver for facsimile messages. The digital paging and facsimile message information would be interspersed with the digital audio information. This "addressability" feature will allow a broadcaster to create software-defined radio sub-audiences, based on national markets or monthly subscription fees. For national markets, certain broadcasts could be restricted to those identification numbers reserved by a particular country for the radios its citizens have imported or its companies have manufactured.

34. Radio networking is now conducted exclusively through geosynchronous satellites utilizing microwave transmit-receive technology to uplink frequencies in the 6 GHz frequency range, and to downlink in the 4 GHz range (C-band). Existing Fixed Satellite Services (FSS) satellites repeat the signal on assigned transponder frequencies, beaming a broad pattern of signals that can cover an entire continent. The signal may be received in any location by an affiliated radio station utilizing low-noise receiving amplifiers centred in the focus of the microwave receiving antennas tracking the satellite.

35. There are three concepts governing the planned interoperability between satellite and terrestrial digital audio radio systems. First, the satellite sound broadcasting system could be used to simply uplink, rebroadcast, and down-convert terrestrially broadcast digital signals. This is similar to the way home satellite dishes currently receive "superstation" television programming via up-links and rebroadcast local television signals. A second possibility is that the terrestrial digital radio transmitters could simply rebroadcast the satellite sound broadcasting signals. The purpose of this method would be to permit continuous, reliable reception of digital audio signals even when buildings or tunnels block the line-of-sight to the satellite. Experiments conducted by the EBU in 1990-1991 proved that digital signal processing techniques permit co-channel transmission of satellite and terrestrial digital audio signals with the radio receivers constructing a

coherent signal based on the strength of the received signal. A third concept is to have independently operated systems that could be received on a single radio receiver. For example, a terrestrial digital radio service might operate in frequencies adjacent to a satellite digital radio service. A single radio receiver would tune across both bands, picking up local (terrestrial) broadcasts on one band and national (satellite) broadcasts on the other.

36. The potential benefits of satellite-terrestrial radio interoperability have reinforced the need for standardization. Digital radio standards must be agreed upon at a detailed technical level to ensure that a radio can operate with both a satellite system and dozens of local digital broadcasting stations. Much of the work towards digital standardization is being carried out in the ITU. However, it now appears that different standards will be adopted for Europe, the United States and other countries and regions. Countries that are located on or near the equator have relatively high satellite elevation angles which will minimize the need for terrestrial repeaters. Hence, a simple down-converting and demodulation of satellite signals for listening over existing radio sets may prove to be the most sensible approach.

37. It is generally accepted that satellite sound broadcasting provides an economic means of covering a wide area with a radio signal. Current digital satellite radio projects have channel costs that compare favourably to those of major international short wave broadcasters. However, the latter group accesses millions of existing shortwave radios, while a satellite radio broadcaster will initially face a dearth of radios at the inception of service. A digital radio must include, at a minimum, an antenna, down-converter, demodulator, and audio decoder. An audio processing board, speaker, and housing will generally also be needed. The prices of currently available satellite radios, though comparable to those of other high-fidelity audio equipment, are still significantly higher than those for standard analogue radios. However, because there are over 2 billion standard analogue radios in use, more than the number of telephones and television sets combined, it is hoped that manufacturers will ultimately be able to ensure the economies of scale needed to reduce the costs of digital radios to the level of analogue radios.

38. Consumers need to know that there are attractive radio programmes before they will purchase a digital radio. However, radio broadcasters and programmers will be reluctant to make the switch to satellite sound broadcasting channels in the absence of a large audience. This dilemma might be addressed in three ways: a) Satellite digital radios could be designed into multi-band radios for gradual market growth; b) Satellite digital radios could be sold to developmental aid organizations for free distribution in poorer countries; and c) Programmers' fees could be calibrated to the level of radio set distribution. Since there is little operating cash flow from which satellite sound broadcasting systems can be economically self-sufficient in their early years, such systems generally are proposed as experimental programmes until they achieve a commercial threshold of radio receiver set distribution.

39. The primary purpose of the WARC-92 was to reach global agreement on which radio frequency bands should be reserved for certain new technologies. In addition, this Conference sought to develop internationally agreed-upon rules pursuant to which geostationary and non-geostationary satellites could share overlapping swaths of radio frequencies, and to effect a slight expansion of frequencies allocated for short wave broadcasting in the HF band and for position-reporting in the very-high frequency (VHF) band.

40. In many ways, WARC-92 paved the way for satellite radio broadcasting and for personal mobile satellite communications. Many new space technologies had emerged since 1979 when the last frequency allocating WARC was held. One of the most important of these is Broadcasting Satellite Service Sound (BSS-Sound) which transmits digital audio broadcasts directly from satellites to portable radio receivers. At WARC-92, proponents of BSS- Sound sought approval for use of frequencies in the 1-2 GHz (L-band) and 2-3 GHz (S-band) ranges.

41. The concept of digital audio broadcasting has been under consideration for many years. Finding suitable technical solutions has been an issue within the CCIR for over twenty years. Apart from the well-known needs of all radio broadcasting, digital audio broadcasting has sought to meet wider objectives, including: provision of radio service to remote, rural and developing regions; provision of high-quality reception to portable or car radios; achievement of spectrum efficiency to overcome the problems of spectrum congestion and the limited availability of services; and power efficiency, particularly to meet the needs of satellite transmission systems.

42. "Direct-to-listener" reception from a satellite is a concept that incorporates the idea of reception by mobile, outdoor portable, and indoor portable receivers. What distinguishes radio broadcasting from the direct broadcasting of television is that the receiver/antenna system must work even if there is no direct-line-of-sight to the satellite from the receiver's antenna. Most planned systems using this concept are being designed for rural, suburban and urban use. Some systems under development are concentrating on mobile reception while many consider indoor reception to "table top" radios to be equally important. This collection of requirements necessitated frequency allocations somewhere between 0.5 and 3 GHz for satellite delivery. Lower frequencies would require spacecraft down-link antennas to be very large and higher frequencies would require excessive power levels per broadcast channel.

43. During the 1980s there was not much interest in the introduction of digital audio broadcasting services, either via terrestrial or satellite delivery. Two industry groups, one American and one European, largely within the confines of CCIR activities, studied the possibility of developing feasible broadcasting services. These studies were primarily concerned with satellite delivery. These studies and discussions held at several WARCs, indicated that some developing countries were indeed interested in the introduction of direct satellite radio broadcasts. The main interest from the industrial countries, however, was concentrated on the value of providing "compact disc"-quality audio programming for cars and other vehicles.

44. Between 1988 and 1992, several organizations noted the need, on a worldwide basis, for audio channels with less than CD-quality reception. This prompted more developing countries to become interested in direct radio broadcasting via satellite. Therefore, when WARC-92 was convened, just about every country in attendance was in favour of allocating some spectrum for BSS-Sound somewhere between 0.5 and 3 GHz.

45. Member States of ITU gave WARC-92 the task of finding available frequency spectrum for satellite and complementary terrestrial audio broadcasting. However, the Conference did not specify a delivery system or technology for digital audio broadcasting. It simply allocated spectrum for these services. It also did not deal with spectrum for systems that would only work terrestrially. This was despite the fact that prior to WARC-92, many studies had been conducted on the spectrum requirements for the various broadcasting systems then under consideration or under development, including the system being developed by the Eureka 147 consortium, as well as systems being proposed for use in the United States, Africa, and Asia.

46. When WARC-92 began, it was clear that there were widely divergent views on spectrum allocation for satellite audio broadcasting systems, particularly among the developed countries. For example, the European delegation was opposed to the use of the L-band even though it is much less expensive to utilize than the high frequency S-band frequencies that were advocated by the United States. The final decision of the Conference supported the use of the L-band even though the spectrum will not be fully available in some regions of the world until 2007. It was determined that sufficient spectrum for viable broadcast systems could be provided before then in many countries. The United States opposed this decision and remains committed to using the 2.3 GHz band for satellite broadcasting. The primary reason for this opposition is that the radio broadcasting industry in the United States is only interested in digital audio for improving the audio quality of local terrestrial broadcasting that is conducted under existing licensing arrangements and the overall

structure of roughly 11,000 radio stations. These broadcasters are nearly unanimous in their aversion to the introduction of satellite delivery of digital audio broadcasting, with its wide area possibilities.

47. The final compromise reached at WARC-92 was to allocate three frequency bands. Each nation accepted one or more of these bands, sometimes with conditions limiting their use until 2007. There are some spectrum management nuances related to the introduction of the service on a co-primary basis and the need to coordinate with neighbouring nations, but the following frequency spectra were allocated:

40 MHz in L-band (1452 - 1492 MHz)
50 MHz in S-band (2310 - 2360 MHz)
120 MHz in S-band (2335 - 2655 MHz)

Roughly half of the world's population lives in nations that chose the L-band allocation and the other half preferred one of the S-band allocations.

48. In comparative terms, the new and planned radio broadcasting services received an amount of spectrum nearly twice as large as all previous radio broadcasting allocations combined. Short wave, AM, and FM radio have about 22 MHz total bandwidth, whereas the new BSS Sound service was awarded 40 MHz total bandwidth worldwide, from 1452-1492 MHz; 50 MHz additional bandwidth, from 2310-2360 MHz, in the United States and India; and 20 MHz additional bandwidth in a number of other countries. This band will be used, on the basis of future planning, for satellite digital audio broadcasting only, in conjunction with terrestrial digital audio broadcasting.

49. In the meantime, provision has been made for early system development for national or regional BSS in the upper 25 MHz of each of the three bands and terrestrial use before a Planning Conference around 1998, and in advance of the allocated spectrum being available for primary use by all countries in the Year 2007. The implementation of this service will probably be delayed in some countries or regions because of the difficulties in transferring the existing radio services to other frequency ranges. Spurred on by activities leading up to WARC-92, which dealt primarily with satellite delivery, there has been significant interest in the use of modern digital techniques for purely terrestrial radio broadcasting in the existing radio broadcasting bands (both FM and AM).

50. Several systems are currently being developed to broadcast radio programming directly from satellites in the geostationary orbit to inexpensive home, vehicle-mounted, and portable radio receivers. These projects share a common emphasis on the use of digital signal modulation, audio source information compression into a reduced bandwidth, and transmission in select portions of the electromagnetic spectrum at frequencies from 1452-1492 MHz and from 2310-2360 MHz. Service on some of these systems is scheduled to begin in certain regions in 1994 and global service is expected to be achieved around 2000.

II. SATELLITE DIGITAL AUDIO BROADCASTING SYSTEMS UNDER DEVELOPMENT

A. Worldspace

51. Worldspace is a for-profit corporation founded in 1990 in the United States to develop and provide a worldwide satellite-based digital audio service. Worldspace itself is not a programmer; the company will not originate its own programming, but the company will make satellite-based digital audio broadcasting available to broadcasters worldwide. In short, Worldspace will develop satellite systems and sell the channels on those

satellite systems to broadcasters who wish to provide wide-coverage, high quality broadcast services to their listeners.

52. Worldspace will implement these systems through regional subsidiaries called AfriSpace (covering the African-Middle East region), AmeriSpace and CaribSpace (covering Central, South America and the Caribbean) and AsiaSpace (covering the South-East Asia/ and Pacific rim region). Each regional subsidiary is wholly owned by the Worldspace holding company. The holding company and its subsidiaries are composed of an international consortium of recognized experts in the satellite and electronics industries.

53. WorldSpace has used a market-driven approach to developing its various satellite digital audio broadcasting systems. The company conducted a feasibility study to determine problems with existing radio delivery systems in its targeted regions and then develop solutions to those problems. The main conclusions of this study were:

a) Terrestrially-based solutions for mass-media have been particularly problematic in many of the developing countries due to terrain conditions, large land areas and low-population densities. These constraints were noted in many areas of Africa, Asia and Latin America. These factors indicated that in order to have the desired impact on these regions, satellite systems would be required for digital audio broadcasting;

b) Existing radio delivery systems do not provide these regions with good quality sound. An improvement to the equivalent of FM-quality would represent a significant improvement from what is currently available. Delivery of FM-quality service would be sufficient for a great majority of the markets in these regions and dynamic multiplexing technology could provide higher fidelity sound where market conditions warrant it;

c) There is a need for a wider choice of programming formats. Because of the costs involved in purchasing and operating even a single transmitter, most developing countries do not have the wide array of format choices that have become the norm in radio markets in the developed countries. It was noted that listeners would appreciate having a simultaneous choice of ten or more different formats from which they could choose;

d) A majority of radio listening in the developing countries occurs on stationary receivers, compared to the developed countries where mobile listening is more common. It would therefore not be necessary, for most regions of the world, to spend the additional amount of money to combat the multi-path propagation difficulties that occur in mobile reception environments; and

e) Cost would be the most sensitive element of the planned service in all regions. Radio broadcasting is a cost-sensitive industry characterized by inelastic demand. A related element of the cost equation is that there is a need to gradually increase the number of available channels so as not to immediately saturate the market.

54. WorldSpace is an experiment in region-specific solutions to region-specific needs. This is why it was decided to implement the service in regional blocks that covered Africa and the Middle East, Asia and the Pacific rim, the Caribbean and the Central America and the South America region. As such, WorldSpace was organized into four subsidiaries to implement region-specific systems with a view to ensuring regional participation and representation.

55. One of the key elements in this process of regionalization will be the development of a mixture of programming that has a larger content specifically developed for the region plus other programming reflecting the needs, the cultures, and the world view of nations outside that region.

56. It is expected that there will be three distinctive types of broadcast services that would utilize the Worldspace system. The first group would consist of regional broadcasters such as the Voice of Dubai, Voice of Brazil, Radio Jamaica, etc. The second group is expected to consist of international broadcasters such as the BBC, VOA, Radio Australia, etc., and the third group would consist of specialized broadcasters that would utilize the system because of its capabilities to reach broad audiences. Examples of such broadcasters include the World Health Organization, which would be able to broadcast health and hygiene information to the broad regions; educational institutions which could transmit university or secondary school-level educational programming; and international organizations such as the United Nations Education, Scientific and Cultural Organization (UNESCO) and the United Nations Children's Fund (UNICEF), which could transmit programming consistent with their respective mandates.

57. AfriSpace, one of the regional subsidiaries of WorldSpace, was created with the express purpose of providing a market-based solution to the problem of radio broadcasting on the African continent, particularly in the Sub-Saharan region.

58. In 1993 AfriSpace petitioned the United States Federal Communications Commission (FCC) for permission to construct, launch and operate what would be the world's first satellite-based, direct-to-listener radio broadcasting service covering the African and Middle Eastern region. The Petition before the FCC noted that AfriSpace was organized to sell or lease the channels on the satellite to broadcasters who wish to reach their audiences with better audio fidelity sound and to provide a wider coverage service than is presently available using terrestrial radio broadcasting techniques.

59. AfriSpace will itself not be a broadcaster but only a satellite operator acting on behalf of the broadcasters providing services to the region. The first satellite is scheduled to be launched in 1997 and placed in orbit at 12° W longitude, just off the coast of Senegal and Ivory Coast. The satellite will have a digitally modulated system with nine CD-quality channels (with about 256 kbit/s per channel data rate) which can be dynamically multiplexed into 36 channels, each with a data rate of 64 kbit/s.

60. The satellite system will cover Africa and the Middle East with three beams, each of which will cover approximately 8 million square kilometres. Each beam of the first satellite will have 12 channels. Thus, each channel will be able to reach a large radio audience. In the context of the African and Middle Eastern region, this would mean that each channel would cover over 200 million people spread across approximately 20 countries. This coverage capability would, in turn, facilitate broadcasts of health advisories and other educational and informational programmes to vast numbers of people.

61. On the basis of AfriSpace's petition to the FCC, and the overwhelmingly positive comments that came in from interested public and private institutions, the FCC initiated a process that culminated in a license for the company to construct, launch and operate its proposed satellite system. The 1992 WARC also made a worldwide L-band frequency allocation for the service.

62. AfriSpace has adapted existing technologies and developed new ones to enable low-cost, solar-powered digital radios known as StarMan F™ to receive audio signals directly from its satellites. The StarMan™ radios will be equipped with digital signal processing chips and will be able to receive the signals transmitted by the satellite. This will thus provide a high audio fidelity service with signal quality ranging from the equivalent of FM radio to that of compact discs. In addition, they will be compatible with solar power systems and be able to provide a wide range of useful applications to both rural and urban areas such as tele-

medicine and tele-education. The radios will also have crystal displays to show paging messages and a standard interface that would allow interconnection with computers and printers for teletext information transfers.

63. The satellite itself is expected to deliver anywhere from 50 to 70 channels which will be divided equally among three beams. AfriSpace plans to lease or sell these channels to broadcasters who are currently unable to reach their entire potential radio audiences or that do so with very poor audio fidelity.

B. Systems under development in the United States of America

64. Following the decision on BSS-Sound reached at WARC-92, the United States FCC issued a Notice of Proposed Rule Making to allocate frequency spectrum domestically at 2310-2360 MHz for satellite and complementary terrestrial digital audio radio services (DARS), and at the same time invited applicants for licenses to provide these services. For this purpose, the FCC also accepted previously tendered applications. This process resulted in four DARS applications before the FCC. The proposed systems range from "hitch-hiker" transponders added to direct broadcast satellites already under construction, to a Martin Marietta Astro Space Series 7000-class satellite with a 20-m deployable antenna. Nominal channel bit rates of the proposed systems range from 55 kbit/s for monophonic FM to 384 kbit/s for CD audio. The majority of systems proposed envision CD-quality audio at 128 kbit/s using perceptual domain compression techniques. System capacities ranged from 25-512 channels and all of the proposed systems would provide coverage to the continental United States. Two would also cover Alaska, Hawaii and Puerto Rico.

65. One of the more contentious issues is the provision of CD-quality programming services to moving vehicles. All of the applicants agreed that mobile services are the most important DARS market. However, they disagree vigorously on whether a particular system could provide adequate link margin to provide these services. Similar questions have been raised about receiving DARS signals inside buildings.

Satellite CD Radio Inc.

66. The first system, proposed by Satellite CD Radio Inc. (SCDR), will be based on two, three-axes, stabilized geostationary satellites located at 80° W and 110° W longitude. SCDR's system will use the 2,200 kg Loral FS-1300 spacecraft with 3,300 watts of power. The SCDR system will serve the continental United States with 30 CD-quality channels at a data rate 128 kbit/s utilizing 20 MHz of spectrum, 10 MHz on each satellite. The SCDR system will simultaneously broadcast the same time division multiplex signal from both satellites. The system will lease transponders to programmers and therefore will not provide services directly to end users.

American Mobile Radio Corp.

67. The system proposed by the American Mobile Radio Corporation (AMRC) will be based on two 2,900 kg Hughes 601 class satellites, each with 3600 watts of power that will be placed into orbit at 93° W 101° W. One satellite will provide services to the continental United States and the other will provide services to the continental United States and Alaska, Hawaii, Puerto Rico and the Virgin Islands. AMRC has requested 5 MHz of spectrum for its satellite that will serve only the continental United States and 10 MHz for the satellite that will serve the off-shore areas. AMRC plans to operate as a private carrier and offer four types of channels to distributors and individualized programmers:

- CD-quality channels at 220 kbit/s
- FM stereo channels at 110 kbit/s
- FM monaural channel at 55 kbit/s
- data channel at 9.6 kbit/s

68. AMRC 's nominal configuration is 10 CD-quality channels, 5 FM stereo channels, 5 FM monaural channels, and a single data channel. AMRC also intends to offer free, advertiser-supported services. AMRC's system is designed to transmit to vehicles via low-profile antennas. Higher gain antennas would be used in fixed applications such as on rooftops.

Primosphere Limited Partnership, Inc.

69. Primosphere Limited Partnership, Inc., has proposed a system consisting of two 2,450 kg satellites, each with 4,725 watts of power, to be located at 80° W and 110° W to provide single-beam coverage of the continental United States. The system will utilize the entire 50 MHz in 2310-2360 MHz band on both satellites with opposite circular polarization. The company proposes to provide a total 46 CD-quality channels at 384 kbit/s and 12 FM monophonic channels at 64 kbit/s, with 50 per cent of the channels to be broadcast from each satellite. Primosphere is the only applicant to request that it be regulated as a broadcaster, and the only applicant to propose only advertiser-supported services. (The other applicants propose to be regulated as private operators.) The system will transmit to flat omnidirectional vehicle antennas, and higher gain antennas will be used for fixed applications.

Digital Satellite Broadcasting Corp

70. The system proposed by the Digital Satellite Broadcasting Corporation (DSBC) will use one Martin Marietta Astro Space 7000-class, 3,500 kg satellite with 5,200 watts of electrical power. The satellite will be located at 101° W to provide service to the continental United States, Alaska, Hawaii and Puerto Rico. The distinguishing feature of the DSBC satellite is its 20 m deployable antenna which will form 31 regional spot beams to provide service to off-shore areas and to provide additional services to major population centres, in addition to the single beam serving the continental United States. Each spot beam will be approximately 350 km in diameter. DSBC's application included two system designs: its preferred design will utilize code division multiple access (CDMA) technology and the second, less efficient design would use time-division multiple access (TMDA) technology and would be compatible with all of the other applicants in case TDMA is authorized by regulatory authorities.

71. DSBC intends to utilize the 2310-2335 MHz band, the lower 25 MHz of the band that the FCC has proposed to allocate to these type of services, in order to provide 16 CD-quality channels at 128 kbit/s to the continental United States and an additional 16 CD-quality channels in each spot beam. The proposed DSBC system would provide truly mobile services using omni-azimuthal low-gain vehicle antennas. The choice of CDMA signalling technology for the system would mean that the digital signal processing and audio modules of its DARS receivers can also be used for other CDMA-based services such as terrestrial cellular telephone and mobile facsimile, as well as telephone and data services to be provided by various low earth orbit satellite systems.

C. Eureka 147

72. A European consortium, headed by France and Germany with support from the EBU and many European governments, has moved the process from the design phase to the hardware development phase. In 1988, this consortium, named Eureka 147, demonstrated CD-quality audio transmitted from a terrestrial transmitter into a moving vehicle. French, German, British and Canadian organizations have continued demonstrations, experiments, and pilot broadcasting operations with this system.

73. The Eureka 147 system is being tested primarily for use at VHF just above 200 MHz. The European plan would be to eventually cease broadcasting in the existing FM broadcasting band of 88.5-108 MHz, but in the interim to use the higher VHF frequencies. This may be a lengthy process. The Eureka 147 system

would require a full 1.5 MHz spectral block within which six CD-quality programmes could be broadcast via hundreds of sub-carriers. Each programme would have its sub-carriers spread across the entire 1.5 MHz. spectrum. The sub-carriers of the six programmes would utilize interleaved frequencies, which are signals transmitted over frequencies from two or more sources in time division sequence over a single path. It would not be possible to retain the current structure of local broadcasting, with individual transmitter towers and different coverage patterns, if this system is adopted.

74. All digital audio broadcasting systems have two basic components: the coding system used to compress the audio signals and the technology used to actually transmit the signal. The coding system to be used in the Eureka 147 system is known as MUSICAM. Its design takes advantage of the psycho-acoustic properties of the human ear to significantly reduce the data rate needed for high-quality audio. The primary mechanism used by MUSICAM is known as masking. This relies on the effect that a high level sound on one frequency prevents a low level sound on a nearby frequency from being heard. Hence there is no need to transmit the low level sound and it can be eliminated from the overall signal.

75. Most broadcast quality audio coders produce excellent results for almost all audio output. The challenge is to find out when they do not perform at optimum levels. Extensive listening tests have been done utilizing the MUSICAM technology as well as on a range of other compressed audio coders. These tests have indicated that MUSICAM is virtually indistinguishable from original CD material when operating at a data rate of 256 kbit/s (i.e. 2 x 128 kbit/s). It can, however, produce roughly the same performance at a data rate of 192 kbit/s. It is therefore expected that the initial broadcast standard for the Eureka system will use MUSICAM operating at 192 kbit/s. This is a compression ratio from the original CD material of about 7:1. MUSICAM has also been chosen as the standard for the audio channels on the proposed Moving Pictures Experts Group (MPEG), which is a motion video compression standard to provide both interframe and intraframe encoding for compressed digital TV. It has also been proposed for some of the in-band digital audio broadcasting systems in the United States.

76. The transmission system for the Eureka 147 system is a digital technology known as Coded Orthogonal Frequency Division Multiplexing (COFDM) which groups together several audio channels on one transmitter. It combats the selective multi-path fading by artificially reducing the symbol rate of the elementary carrier transmitted and allowing for symbol guard time. The COFDM system has been designed to broadcast several audio channels as an integrated digital signal from one transmitter. Recent research indicates that the optimum arrangements might be six stereo channels of 192 kbit/s each feeding into a single transmission channel of 1.5 MHz bandwidth. (The transmitted data rate would be over 2 Mbit/s after error correction bits are included.)

77. Such a system need not simply transmit six high quality stereo channels. It could be used for nine medium quality channels (about FM grade), or twelve AM stereo grade channels or more than 30 voice-grade channels. Any mixture of the above is technically possible, including channel splitting at certain times of the day. The Eureka digital audio broadcasting COFDM system will also support single frequency networks. In its simplest form this would see translators on the same frequency as the parent station with overlapping coverage areas. The Eureka system would handle such an arrangement by using the two signals to reinforce reception rather than having the two signals interfere with each other.

78. Terrestrial selective n.ulti-path effect is virtually eliminated in the Eureka system and the limit of coverage is generally well-defined. Performance measurements made at the L-band have shown that coverage is very even throughout a transmitter's service area. Any areas of poor reception such as behind obstacles or in valleys can be rectified with low-cost on-channel translators. The capability of having translators on the same frequency as the parent transmitter also leads to compatible satellite and terrestrial transmissions. A satellite could transmit across a region of the country with terrestrial re-broadcast transmitters on exactly

the same frequency being used to reinforce the signal in shadow areas. This feature may also allow a reduction in satellite power as primary satellite coverage would mainly need to serve open space.

79. The ability to support translators on the same frequency as the parent transmitter is an important feature of the Eureka 147 system for many countries. The transmitter power levels needed to provide adequate coverage at the L-band has not yet been fully determined. Present indications are that a six-channel system will require less power than a single channel transmitter for comparable coverage.

D. Systems being developed by the European Space Agency

80. Digital audio broadcasting is a new service that the European Space Agency (ESA) is investigating for future European satellite systems. ESA is actively promoting this service in their various mission options including non-geostationary satellite systems. One of the main technical challenges of this new service lies in the fact that the geostationary orbit is less suited for a large penetration of radio broadcasting services. ESA has therefore been looking with increasing interest to the exploitation of new orbit alternatives such as the circular low Earth orbit (LEO), the intermediate circular orbit (ICO) and the multi-regional highly inclined elliptical orbit (M-HEO). The utilization of these orbits poses several technical challenges. ESA's experimental programme called Archimedes will explore these challenges by flying one or more experimental satellites by 2000 that will be representative of future sound broadcasting and personal communication missions.

81. Systems based on circular orbits could provide global coverage but would require a fairly large constellation of satellites to do so. An alternative approach which would dramatically reduce the size of the required constellations, is based on the use of highly elliptical orbits (HEO). HEO constellations have been successfully used since 1966 in the former Soviet Union for community TV reception and emergency communications. More than 100 Molniya satellites (each with a relatively short operational lifetime) have been launched into elliptical, 12-hour orbits of the same name.

82. HEO constellations are well suited for regional or multi-regional services. A satellite in HEO lies in a plane that is inclined approximately 63 degrees with respect to the equatorial plane. This gives the satellite the advantage of being viewed at very high elevation angles in northern or southern regions. This compensates for the higher slant-range in comparison with LEO or ICO systems, and makes HEO satellites well suited for radio broadcasting in northern latitudes. It also allows high signal availability without penalizing the system economy by imposing large link margins. An advantage of using HEO satellites in northern latitudes is that when low-gain user-receiver antennas are used, as in the case of personal receivers, higher gain can be achieved (2-3 dB's more) compared with geostationary satellites.

83. In a HEO constellation the satellites are not stationary and are therefore used in the orbital arc around the apogee where they exhibit quasi-geostationary behaviour. The number of service areas is equal to the number of apogee points on the Earth ground track. HEO orbits with more than one coverage area are called multi-regional orbits. The number of satellites for a given constellation is determined by the number of service areas, multiplied by the orbital period, divided by the selected duration of the active arc.

84. Some broadcasters have expressed interest in satellite broadcasting, primarily because of the high availability rates and audio quality that HEO systems could provide. However, funding the development and launch of a full constellation of satellites is beyond their resources. Consumer electronics manufacturers are also interested in satellite radio but are clearly waiting for concrete implementation plans for the space segment before they commit resources to product development, manufacturing and marketing. Because of this widespread interest in satellite radio systems, and the reluctance to commit financial resources until the technology is fully proven, it is evident that the research and development funding and initial start-up costs

of an HEO or other type of constellation for satellite radio will have to come from the public sector. ESA's Archimedes programme will promote the possibilities of satellite communications.

85. In the framework of the Archimedes project, ESA is willing to pursue utilization of HEO constellations for multi-regional personal and sound broadcasting services. Over the course of the Archimedes programme ESA plans to target the development of an experimental satellite to demonstrate the viability of later operational systems.

86. Blockage of the satellite line-of-sight and multipath effects would degrade DAB services to a non-acceptable level. This is translated into the requirements of high elevation angles and high received power flux density over wide areas. The importance of satellite elevation angles has been demonstrated in several field measurement campaigns in the L- and S-bands. This problem is of particular relevance in all northern regions. A geostationary orbit-based service must include propagation margins in excess of 10 dB to serve those regions, which implies a design solution based on high-powered spacecraft with a large and complicated antenna system resulting in a high cost for telecommunication services.

87. ESA has studied the Tundra orbit, an elliptical orbit that has an orbital period of 24 hours and an inclination of 63.4° to the equatorial plane, as well as the Molniya orbit for coverage of Europe with high elevation angles. More recently, ESA has focused its attention on two types of Multi-regional Highly-Inclined Orbits (M-HEOs), the M-HEO(8) and M-HEO(16) orbits.

The M-HEO(8) system

88. The M-HEO(8) system being investigated by ESA is particularly well-suited to services such as personal communications and sound broadcasting. It would allow:

a) High availability rates and continuous 24-hour service tailored to cover the three most important market areas of the world, i.e. Europe, Far East and North America; and

b) The use of a minimum number of satellites for continuous coverage of these three service areas. The apogee at 26,000 km would allow power savings in comparison with other HEO alternatives or geostationary satellites. The lower apogee altitude M-HEO satellites would also offer a considerable advantage over the other HEOs in terms of orbit mass that can be delivered by a given launcher.

89. In its basic configuration, the M-HEO(8) system will be composed of a constellation of six satellites in 8-hour elliptical orbits. This six-satellite configuration would enable users to receive radio signals from satellites that would always be visible due to their high elevation angles. The coverage area of the M-HEO(8) system would include all of continental Europe where the minimum guaranteed elevation angle of more than 45 degrees would always be achieved. The other coverage areas are Japan, China, other parts of Asia, the Commonwealth of Independent States, Canada, the United States and Mexico, where elevation angles would always be greater than 40 degrees.

90. In its baseline configuration the M-HEO(8) system would provide integrated digital broadcasting services that would include the possibility of user interaction. Examples include:

- news and basic radio text;
- bilingual news and stereo music, basic radio text;
- multilingual news and hi-fi stereo music;
- multilingual news and CD stereo music, enhanced radio text or TV for pocket receivers;
- paging and messaging services;

- interactive services providing users with a low bit rate response channel. The maximum bit rate is around 50 bit/s;
- navigation services integrated with meteorological data broadcasting.

91. In order to deliver the necessary power flux density to provide these services to small receivers, multi-beam antenna coverage of the three service areas would be necessary. The M-HEO(3) coverage foresees the use of a reconfigurable antenna system providing five beam coverage (four spot beams and one global beam) in each service area. The four spot beams would be arranged in the three service zones in order to match linguistic and geographical constraints. The transponders are intended to provide a flexible share of resources according to market and user population needs. The transponder can be configured to provide a given distribution of services with different quality and power levels. It is fundamental that the selected modulation and multiplexing technique allows such flexible allocation of bandwidth and power resources. Approximately 1,000 watts of DC power will be allocated for the payload.

92. In order to simplify the design of the satellite, there will be no frequency reuse in a given service area, but in order to minimize the overall frequency requirements of the system, frequencies would be reused in different regions. The overall down-link frequency requirement will be roughly 10 MHz for operations in the three service areas. Due to the high elevation angles, frequency coordination would be simplified both with respect to geostationary satellites and terrestrial links.

93. The up-link of radio programmes would take place in a ground station equipped with 5 m tracking antennas. Each satellite will be tracked independently. A single up-link location above 58° N could address the European, Far Eastern and North American loops at the same time with a minimum satellite look-up angle of 5 degrees. Given that the up-link antennas would never cross the geostationary arc, the C-band can be used without the problem of coordination with respect to GEO satellites.

94. The sound broadcasting service is intended for a wide array of users in the three service areas. Users would be equipped with terminals that can be subdivided into three main classes:

- table-top radios equipped with directional antennas with adjustable elevation and azimuth controls;
- mobile receivers installed in moving vehicles with medium gain antennas with omni-azimuthal patterns;
- personal "walkman-type" receivers with low gain antennas with omni-azimuthal patterns.

E. INDOSTAR

95. The government of Indonesia has begun a programme for the development of social communication and education in which the country will become more industrially-oriented between 1994-1998. While emphasis on education has increased national literacy substantially, there are still many rural areas of the country where radio and television services, a principal and effective means of education and information dissemination, are not available.

96. The broadcasts of Radio Republic Indonesia (RRI) currently reach 67 per cent of the Indonesian archipelago and 80 per cent of its total population. The broadcasts of Television Republic Indonesia (TVRI) cover 37 per cent of the nation's territory and reach 68 per cent of the population. Nevertheless, there are still approximately 36 million Indonesians who are unable to receive RRI broadcasts and approximately 57 million Indonesians cannot receive TVRI. In addition to the coverage limitations experienced by the nation's principal broadcasters, studies have shown that an increasing number of foreign radio and television programmes have caused interest in locally-produced radio and television programmes to decline.

97. The Government of Indonesia therefore believes it is necessary for the country to develop a system capable of broadcasting high-quality radio and television programming to all its citizens. To accomplish this goal, Indonesia is investigating various transmission media through which it will be able to broadcast such programming to the largest number of people at the lowest possible cost to both the government and the people of Indonesia.

98. Distribution of radio and television programming is presently accomplished using several different transmission media. Telephone transmission circuits, designed primarily for voice circuits, not high fidelity radio, are often used for transmitting radio programming from one point to another due to the availability and extensive coverage of the telephone network. For several RRI stations, national programmes are relayed from Jakarta via short wave as the principle means of transmission. In some cases, programming received via short wave is then re-broadcast by a local medium wave transmitter, or received directly by listeners using short wave receivers.

99. Indonesia began the INDOSTAR project with the objective of improving the coverage, quality and affordability of broadcasting services within Indonesia. One of the goals of the programme is the development of an Indonesian direct broadcasting satellite (DBS). This DBS programme consolidates national broadcast requirements and services into a single cost-effective broadcast resource. The DBS system currently under development is being closely tailored for national coverage and programming requirements. Direct reception of both radio and television programming by the individual user in Indonesia, using low-cost receivers, directly from a standard quality broadcast coverage to the entire nation, is the fundamental goal on which the INDOSTAR programme is based.

100. The INDOSTAR system has been designed to take advantage of recently proven technology to provide excellent quality broadcast television and radio programming, simultaneously, to all of Indonesia. This programme, based on existing Lightsat technology, represents the most cost-effective method of delivering these services, while at the same time insuring quality broadcast reception. In addition to the advances made in Lightsat spacecraft technology, radio and television receiver technology is now taking advantage of recently pioneered digital processing, coding data compression and micro-electronics technology. These advances in receiver technology, coupled with a Lightsat satellite, provide the quality and quantity of services previously only available to the affluent, from very large satellites which typically cost three to four times what the INDOSTAR satellites are expected to cost.

101. The INDOSTAR DBS programme will provide both TV and radio broadcast services, direct from a geostationary satellite to TV-sets and radios without the need for expensive terrestrial re-broadcast stations for less than 10 per cent of the costs associated with short wave transmission operations, with substantially higher quality signals and complete national coverage. This programme is being developed as a "turnkey" project with launch of the INDOSTAR-1 satellite scheduled for mid-1995. The INDOSTAR system consists of three major elements: the Master Control Station (MCS), the INDOSTAR spacecraft and the ground segment. The MCS includes both a tracking, telemetry, control and monitoring facility, and a program uplink facility that will be used to collect, format and transmit radio and television programming to the satellite. The ground segment is comprised of three different types of receivers: two for TV reception and one for radio reception. Launch services, operation and management services, training, insurance and the development of in-country satellite TV and radio receiver manufacturing capabilities are also included in this broad programme.

102. The INDOSTAR radios are being designed to operate in any environment and will be capable of receiving digital audio broadcast from many satellites simultaneously without changing the antenna position or location. The INDOSTAR radio will be able to receive hundreds of radio channels in the future with quality varying from FM monaural to near CD-quality stereo. The INDOSTAR-1 satellite will broadcast up

to eight channels of varying quality radio programming. Additionally, INDOSTAR radios will be capable of receiving CD-quality terrestrial radio broadcasts broadcast via low power transmitters in major population centres, without requiring any modification or enhancement to the radio.

103. The satellite will receive transmitted programming signals and without modifying the signal, other than to change its frequency and boost its power level, re-transmit the programming signals towards the Earth in a "bent-pipe" fashion. The INDOSTAR satellites will broadcast radio programming in the L-band. Radio channels will be agile enough to allow the carriers to be moved to any location in the BSS-Sound band. This design characteristic supports mitigation of interfering signals. Through advanced data error correction and the use of data compression, the power flux density levels of the broadcasts arriving at the Earth's surface will be of such a level that they will not cause interference with any existing microwave of terrestrial land mobile systems in use today.

F. INTELSAT Digital Audio Distribution service

104. For nearly three decades, INTELSAT has worked closely with the world broadcast community to build a reliable and flexible international satellite system. The INTELSAT system provides coverage via its satellites over the Atlantic Ocean, Indian Ocean, Asia-Pacific and Pacific Ocean service regions to meet virtually every telecommunications need. For radio broadcasters interested in penetrating new markets, INTELSAT's Digital Audio Distribution (DAD) service can deliver high-quality radio programmes to any market in the world. DAD uses the latest in digital signal compression technology, and is intended to allow broadcasters to offer higher-quality, low-costs programming in order to increase listenership and profitability.

105. The DAD service is able to provide the following services to AM/FM stations with small C- or Ku-band antennas, international gateway earth stations or cable head-ends:

- digital distribution of audio for news, sports, music, talk programming and special events;
- point-to-multipoint distribution services worldwide;
- channel capacity provided at any data rate for any quality service (customers can set their own parameters). Audio quality available from CD quality channels (20 KHz) to nominal quality voice channels (5 KHz);
- full or fractional transponder leases;
- real-time transmission.

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